Constructing a macro-actor in practice:

the case of Wave Hub

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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Abstract

This research examines whether study of the controversial evolution of energy systems and emerging energy technologies can contribute to the debates in energy policy and STS, especially those concerning the ongoing search for solutions to energy and environmental problems through the promotion of low-carbon technologies. The focus of this study is on the emergence and growth of a technological project in the renewable energy sector, Wave Hub in Cornwall, UK. The analysis, informed by actor-network theory, helps to explore the emergence of Wave Hub as a complex socio-technical system and a macro-actor. The case study reveals that the project is associated with various controversies and problematic temporalities. The construction of credibility and viability of the technological project is explored, including the 'public face' of the project, various meanings attributed to Wave Hub and its symbolic capital. The discourse around Wave Hub is critically reviewed, as regards stakeholder assumptions about the technological feasibility of the project. Consideration is also given to the political dimensions of credibility, including the promissory role of policy discourse. An actor-network theory approach helps questioning the idea of policy as 'macro context'; the utility of an analytical approach to policy as an actant is thus investigated. I ask to what extent, and in what sense, policy can be understood as an element of an actor-network, not merely a context. Furthermore, this helps to build a critical discussion around the evolution of the actor-network with policy as its active element and critically assess to what extent this approach might help to understand the destiny of a technological project. The politics of expertise in the case of Wave Hub is shown to play a critical role for the 'credibility-economy' of the project. Exploring how the expertise is understood and performed in the case of Wave Hub, I consider the question of the self-representation of experts and how the expert knowledge and the expert status are constituted. Studying the contestation of expertise and its categorisation helps to analyse various forms of collaboration formed around Wave Hub, but also antagonism which was revealed between different groups of experts.

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Abbreviations

ANT	Actor-Network Theory
BIS	Department for Business, Innovation and Skills
CCS	Carbon Capture and Storage (or Carbon Capture and Sequestration)
CfD FiT	Contracts for Difference – Feed-in Tariffs
CPA	Coastal Protection Act
DANTE	Discursive Actor-Network Theory Enterprise
DBERR	Department for Business, Enterprise and Regulatory Reform
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food & Rural Affairs
DTI	Department for Trade and Industry
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
EPOR	Empirical Programme of Relativism
FEPA	Food and Environmental Protection Act
MCA	Marine and Coastguard Agency
MEAD	Marine Energy Array Demonstrator
MEAP	Marine Energy Action Plan
MOD	Ministry of Defence
MRIA	Marine Renewables Industry Association
MRCF	Marine Renewables Commercialisation Fund
MRDF	Marine Renewables Deployment Fund

MRPF	Marine Renewable Proving Fund
NaREC	National Renewable Energy Centre
NFFO	Non-Fossil Fuel Obligation
PCU	Power Connection Unit
PRIMaRE	Peninsula Research Institute for Marine Renewable Energy
RDA	Regional Development Agency
REA	Renewable Energy Association
RO	Renewables Obligation
ROC	Renewable Obligation Certificate
SAS	Surfers Against Sewage
SCOT	Social Construction of Technology
SSK	Sociology of Scientific Knowledge
SST	Social Study of Technology
STS	Science and Technology Studies
SWRDA	South West of England Regional Development Agency
TSB	Technology Strategy Board
UKCMER	UK Centre for Marine Energy Research
WATERS	Wave and Tidal Energy: Research Development and Demonstration Support fund
WATES	Wave and Tidal Energy Support scheme
WEC	Wave Energy Converter

In loving memory of my father,

philosopher and sociologist Dr. Rashid Islamov

Chapter 1. Introduction

Renewable energy has come into focus in light of search for new sources of energy and the problem of energy security, reduction of fossil fuel emissions and development of clean energy, as well as creating a new industry and even economy. The theme of renewable energy persists on political agenda and is a matter of ongoing political concern. It is widely debated in society and is often perceived as controversial.

Policy documents and academic literature suggest some types of renewable energy are more advanced on their way to commercialisation than others. It is believed that the potential for growth in marine renewable energy is substantial, but there are many unanswered questions about how that growth can be achieved, especially in times of economic austerity. Marine energy is seen as a sector where the UK could become a front-runner in developing and deploying new technologies. As stated in policy documents, the UK is presented as having the potential to become an international leader in developing new marine energy technologies. The publics are being convinced that waves are pure energy and hence a resource to be put to work for cleaner and greener energy regimes. The promise of extraction of energy from waves is largely construed as a key potential contributor in tackling the problems of climate change; sustainability; green energy and economic development promised to areas which accommodate wave energy projects.

Research and development programme for exploring wave energy supported by the UK government started in 1970s as a response to the oil crises, but was scaled down and eventually abandoned, largely due to scepticism regarding economic viability of wave energy. Later, climate change debates put renewable energy back on the agenda. Although wave energy is a relatively immature sector compared to, for example, wind or solar, it is anticipated that wave energy would be able to contribute to emission cut targets beyond 2020.

Exploration of the potential of waves is a subject of extensive research in the UK. Wave energy conversion is perceived as comparatively immature technology, and there are a variety of different devices – wave energy converters developed by different companies in the UK and elsewhere in the world. Factors, such as hostile offshore environment, high costs, lack of skills, limited investments and uncertainty regarding the future of wave energy sector are presented as obstacles for development of emerging wave energy industry.

Since wave energy converters are not proven technologies, it is seen as extremely important to continue testing and operating in real sea conditions in order to move to full scale commercial deployment. As such, the role of testing centres and facilities is crucial for further development of the sector, and several of them have been built in the UK. One of the biggest projects of this kind is Wave Hub which was chosen as a case study for this thesis.

At the time of this study, some changes in the UK political landscape were happening. The most important is, probably, the change of the government in 2010, when the Coalition Government was formed. It made a pledge to be ‘the greenest government ever’, announced the intention to encourage marine energy in the UK and demonstrated a strong political investment in driving new technologies.

Nevertheless, at the time of data collection 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. The process of policy shaping was still ongoing and renewable energy policy was in state of flux, shaped by many parameters, influenced by many stakeholders, involving deliberations about its directions, relevant constituencies, etc. This uncertainty was reinforced by the situation with differentiation between the regions in terms of financial mechanisms to support wave energy (i.e. ROCs). The generally greater ability of the Scottish parliament to devise its own strategy led to announcement of 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.

Due to all these factors, wave energy sector in the UK appeared to be an interesting and promising site for studying technological change and underpinning policy landscape. Moreover, it can be seen as a strategic site for studying related policy as it provided an opportunity to examine how the process of policy shaping is occurring and see renewable energy policy in the making. It becomes especially significant in the context of debate about energy transitions and sustainable energy futures providing empirical underpinning of such processes.

Aims and objectives

In this thesis I present a qualitative study with some ethnographic elements which explores the dynamics of socio-technical change associated with construction of a wave energy project, Wave Hub. The aim is to produce an empirical study of Wave Hub and explore potential of STS approaches to open up the black box of this technological project. The rationale behind this case study is based on the idea that it can help to approach, and contribute to the debates in STS about technological design and energy systems change, especially in relation to complex technological configurations aiming to search for solutions to energy and environmental problems through promotion of low-carbon technologies.

The focus of this study is on the emergence and growth of a technological project in the renewable energy sector – Wave Hub in North Cornwall, UK. It is largely spoken about as a renewable energy project which aims to facilitate the deployment and further development of marine energy technologies in the UK. My analysis informed by actor-network theory, will help to explore the emergence of Wave Hub as a macro-actor and examine numerous controversies about its design and destiny.

Building a historical narrative – a 'possible history' of the Wave Hub project – I pay special attention to the controversial aspects of its development, such as a consenting process, the interests and involvement of different actors, the role of policy and regulation in the field. Public and stakeholder engagement and their role in modulating a project's trajectory are the key issues that I explore. I study in detail the long and complicated negotiation process with different groups on the anticipated impact of Wave Hub, which demanded a resolution of conflicting interests, and pay special attention to political dimensions of this process.

The main purpose of exploring the emergence of a macro-actor and examining numerous controversies about its design and destiny is to investigate the idea of policy as an actant. I build a critical discussion around the evolution of an actor-network with policy as its active element and critically assess the extent to which this approach might help to understand the destiny of Wave Hub. Thus, the central research question investigated is to what extent, and in what sense, policy can be understood as an element of an actor-network, not merely a context.

Another key research question in this study is how credibility and viability of a technological project are constructed. I examine deliberations concerning viability of expectations about the completion of the project and its pivotal role in early commercialisation of the wave energy sector. I also explore the 'public face' of the project, and discourses justifying its idea and implementation, as well as various meanings attributed to Wave Hub and its symbolic capital. Examining the thesis about Wave Hub as a product of implementation of contemporary renewable energy policy in the UK allows me to consider political dimensions of credibility construct, i.e. the performance of policy and the promissory role of policy discourse. I also investigate the development of a 'credible' design solution and its implementation in the situation of uncertainty through legitimating decisions and accounting for failures, as well as deliberations about lessons learned by those involved in the project development.

The question that needs to be answered in the light of the discussion of credibility of Wave Hub is whether the politics of expertise might affect in some way the credibility of the project. The dynamics and politics involved in the construction of expertise around a technological project is explored. Being perceived as a 'challenge for experts', this project was presented as extremely controversial, with a lot of disagreement and differences in opinions regarding its success and the professionalism of those involved in its development. I study the discourse that the expert community formed around Wave Hub with the focus on those groups who positioned themselves as experts and whose expert status was recognised by others (i.e. professional expertise). My task is to show how the expertise was understood and performed in the case of Wave Hub and for which purpose, how the expert knowledge and the expert status are constituted. I also study the contestation of expertise and its categorisation, collaboration and antagonism which was revealed between different groups of experts. This study provides an insight into the inner politics of expertise around the Wave Hub project, including various tensions and self-(re)presentation of experts. I also answer questions about the role and status of research institutions as boundary organisations involved in the development of a technological project. The analysis of expert discourse will help to increase understanding of how objects of expertise, e.g. waves, are constructed (understood and framed) in scientific discourse.

Significance of the project

The significance of the dissertation stems from its demonstrating an attempt to explore the potential of Science and Technology Studies for studying renewable energy projects. I re-examine some approaches in STS, both in discourse analysis and in actor-network theory tradition. In particular, such concepts as possible history, macro-actor and credibility-economy have turned out to be useful for my analysis of the wave energy project.

In this thesis I extend the concept of macro-actor to studies of renewable energy and demonstrate the utility of this approach for analysis of emerging industries, such as wave energy industry. I draw on a concept of macro-actor to investigate a technological project, Wave Hub, as a large complex socio-technical system and an actor-network. This approach allows me to explore heterogeneity and fragility of an actor-network, to understand dimensions of a macro-actor that might not be apparent, and to show how it comes into existence, appreciating Wave Hub as a macro-actor ‘in the making’.

Using a narrative historical approach I explore this renewable energy project in order to locate it in relation to renewable energy policy and dominant narratives around renewable energy, particularly in the UK. An ANT-informed approach allows me to step beyond contextual understanding of policy and to suggest a new way of thinking about the renewable energy policy, developing an idea of policy as an actant and providing an insight into complexity of policy network.

This thesis can also be seen as an attempt to elaborate an alternative perspective to evaluate the potential of renewable energy projects, not least through making participants' voices heard in the case study. Bringing an STS-formed practice approach to renewable energy studies, namely, the interview-based analysis, helped to reveal many aspects of the construction of Wave Hub missing from the public (including policy) discourses associated with the project. Looking at the back-stage of the project helped to get a glimpse into controversies, contradictions and antagonisms which appeared central to the construction of the project's credibility as an emerging property of a macro-actor and a multidimensional construct. This study provides an insight into the politics of expertise surrounding a big technological project and allows us to understand how it was constructed as a credible expert endeavour. It also dissects the notion of what constitutes wave energy as part of sustainable energy futures and policy discourse.

Theoretical framework

This study is an interdisciplinary research project. The theoretical base of my research is formed by studies in renewable energy, innovation studies and sociology. In order to answer research questions raised in this study I referred to the literature in the field of renewable energy policy and STS, as well as actor-network theory. The methodological stance is also a combination of approaches, such as ANT and discourse analysis.

The literature in the field of renewable energy helps to understand the conventional approaches to analysis of renewable energy policy and related themes in academic literature to date. In energy policy and energy transitions studies policy is traditionally perceived as an institutional context and regulatory framework. The main purpose of discussing this literature is to elaborate focus to critically evaluate the externalist view of policy as a macro context in the so-called positivistic literature on renewable energy and innovation. Although the studies in renewable energy do not entirely engage with a thorough-going constructivist perspective on science and technology, they provided a starting point for discussion of policy issues, mechanisms and instruments, technological innovation and energy systems. This body of literature is often represented as a mixture of academic and 'grey' literature (e.g. policy documents), and as a rule, is practice-oriented. Relevant policy documents also perform as a source of data and as an object of analysis.

The contemporary technological developments require approaches sensitive to practices of and expectations about technological developments. As the focus of this study is on wave energy technologies and conceptualisation of Wave Hub as a technological object, a ground on which I stand comes foremost from STS. The STS literature is the core of the theoretical framework where the variety of perspectives such as the social construction of technology, the concept of technological systems, the network approach, macro-actor and related concepts were put forward by such scholars as Michel Callon, John Law, Susan Lee Star, Trevor Pinch and Wiebe Bijker, Bruno Latour; the work by Donald McKenzie, Stephen Hilgartner, Sheila Jasanoff, Helga Nowotny, Andrew Webster and others forming a theoretical ground of my research. STS can be thought about as a vast, complex, multidisciplinary enterprise, a 'set of sensibilities', to materiality for example, to process, and to specificity in many different fields (Woolgar et al, 2009). The ideas developed within STS and most relevant to my thesis are that social and material cannot be distinguished; the human-nonhuman distinction is seen as a consequence or effect of relation; the attempts to measure or scale the macro and micro are similarly relational effect; technology cannot be perceived as an autonomous thing and involves debate about the politics of technology.

Actor-network theory was especially useful for my analysis as a theoretical resource. ANT suggests employing the same analytical and descriptive framework dealing with both human and nonhuman actors which form a network and wherein their identities are defined through their interactions with other actors. As such, it refuses to reduce explanation to natural, social or discursive categories while recognising the significance of each. ANT can be employed for analysis of a technological project and its environment. The idea of heterogeneity of actor-networks helps to explore the construction of deliberations and asymmetries between technical and non-technical, human and nonhuman elements which are equally important for the construction of a sociotechnical network. The concept of translation, used to describe processes through which actors relate to one another, can help to conceptualise what is actually occurring during the process of innovation and to bridge the gap between various aspects embedded and combined in technology, which in turn can be seen as an actor-network (or a macro-actor). ANT approach to the ideas of scale, micro/macro distinction and context/content dichotomy also makes it a suitable strategy for studying technology development, success or failure of technological innovation, and its trajectory.

The potential of such an approach needs to be proven, but at least in my case study it has brought to light perspectives to renewable energy developments largely missing from dominant policy discourse.

Constructivist thinking and qualitative approach is central to my research. I use in-depth interviews (semi-structured and narrative); documentary data analysis, including the assessment of existing published data; observations. The range of the participants includes different stakeholders, such as device developers, researchers and scientists, regional and local authorities, professional associations and industry experts, and other social groups having interests in the Wave Hub project.

Structure of the thesis

The thesis is organised as follows. In the second chapter I provide a critical review of the literature to my investigation. I look thematically and in some depth at some theories and concepts that are employed for empirical data analysis. The research questions are formulated at the end of this chapter. Chapter 3 aims to consider methodological concepts which have influenced my approach to methodology, political and ethical issues, as well as practical aspects of data collection, and the challenges and choices I faced in the process of data analysis. It also includes some reflections on conducting my fieldwork. Chapter 4 delves into the possible history of the Wave Hub project which can serve as an introduction to the case study. I start my analysis by introducing the concept of a macro-actor and employ an ANT approach to discuss various stages of project's evolution and its most controversial aspects. Chapter 5 investigates an analytical approach to policy as an actant. Here I discuss in brief the wave energy industry and renewable energy policy in the UK and analyse policy discourse. I also discuss the notion of policy and its meaning for the purpose of my research, the role of policy in the construction of a macro-actor and the role of promissory discourse in building credibility of the Wave Hub project. In chapter 6 I analyse the construction of the credibility of Wave Hub which is split in two sub-questions: the construction of credibility of Wave Hub as a macro-actor, and legitimate decision making at different stages of the project development. Chapter 7 brings into the open a discussion about the politics of expertise around Wave Hub. This chapter consists of several sections that discuss waves and wave energy as objects of expertise, categorisation of expertise with particular focus on the politics of commercial expertise and the production of academic expertise around Wave Hub, as well as the main antagonism between them. Chapter 8 pulls together concluding thoughts and consideration about what has been gained from this research project and what could be the implications of this study for STS and renewable energy research.

Chapter 2. Literature Review

2.1. Introduction

In this chapter I aim to provide a review of the literature that forms a theoretical ground for this thesis. I will look thematically and in some depth at some theories and concepts that will be employed for empirical data analysis. Some of them (e.g. in the field of Science and Technology Studies) are not specifically used for analysis. However, having a conceptual understanding of their contribution to theories developed in STS and its conceptual approaches will assist in better understanding the rationale behind this study, its narrative features and discussion of the research questions.

In the first section of the literature review I will draw attention to a vast body of literature in the field of renewable energy. Most of the studies in renewable energy (and marine energy) employ a positivist approach representing both quantitative and qualitative research, and, as a rule, are practice-oriented. This literature helps to understand the traditional approaches to analysis of renewable energy policy and related themes in academic literature to date, where policy is often understood as a macro context. Although the use of this literature for theoretical analysis of my empirical data is limited, it provides a starting point for discussion of policy issues, various mechanisms and instruments, technological innovation and energy systems in this thesis. The literature in renewable energy policy often represents a mixture of academic and so-called ‘grey’ literature, i.e. policy documents produced by governments, selected committees’ reports, etc. which will be analysed in Chapter 5.

This thesis is based on studying a technological project, Wave Hub, as a macro-actor and its various aspects and dimensions. As the focus of this study is on wave energy technologies and conceptualisation of Wave Hub as a technological object, it determines the choice of a theoretical framework. Science and Technology Studies possibly can offer such relevant framework. Thus, in the second section I will draw attention to an established but still developing body of literature – Science and Technology Studies, which is sometimes schematically divided into the sociology of science (or science studies) and technology studies, reflecting my own particular interest in the field from where I borrowed some useful concepts. I will explore evolution of approaches in STS, including social construction of technology (SCOT), technological systems approach and actor-network theory (ANT). The ideas about political character of technology, construction of credibility and expertise have been developed within STS and are most relevant to this study.

In the third section of the literature review I will provide a general overview of actor-network theory and its main principles and concepts that will also contribute to the theoretical framework and help to build a methodological strategy for my analysis. It can offer concepts and approaches that I find useful for studying technological objects, i.e. a macro-actor, irreversibility and stabilisation of networks, heterogeneous engineering, symmetrical treatment of both human and nonhuman actors which form a network. Thus, ANT can be employed for analysis of a technological project and its environment as the idea of heterogeneous nature of actor-networks helps to link technical and non-technical, human and nonhuman elements which are equally important for the construction of a sociotechnical network. The concept of translation, used to describe processes through which actors relate to one another, can help to conceptualise what is actually occurring during the process of innovation and to bridge the gap between various aspects embedded and combined in technology, which in turn can be seen as an actor-network, or more specifically for my study, as a macro-actor. ANT approach to the ideas of scale, micro/macro distinction and context/content dichotomy also makes it a suitable strategy for studying technology development, success or failure of technological innovation, and its trajectory. At the end of this section I will draw attention to current ANT studies in the field of renewable energy.

The problem of context and content is central for understanding the evolution of technological projects, especially where the policy is involved, and is an object of STS inquiry. STS, and in particular ANT, perspective helps to move to the problem of context/content dichotomy. In the final section of my literature review I will discuss the existing studies which explore the idea of context, contemporary approaches to understanding the concept of context and the question of the emergence and transformation of context. As policy and regulations are often referred as a framework or context for the case study, this literature will help to develop my approach to analysis of policy and its perfomative role in the case of Wave Hub.

Thus, it is useful for the purpose of further analysis of policy issues and relevant empirical data which is based on the idea that the distinction between context and content is being constantly negotiated and generated by actors; this distinction is relational (depends on a perspective, individual or emerging through collective deliberations).

2.2. Key directions in renewable energy research

Most of the studies in the field of renewable energy (and marine energy) employ a positivistic approach. They represent both quantitative and qualitative research, and, as a rule, are practice-oriented.

This literature helps to understand the conventional approaches to analysis of renewable energy policy and related themes in academic literature. It provides a starting point for discussion of policy issues, various mechanisms and instruments, technological innovation and energy systems in this thesis.

This field often represents a mixture of academic and so-called 'grey' literature[1] (policy documents produced by government departments; selected committees' reports; government affiliated organisations, i.e. Carbon Trust; NGOs etc). The references to policy documents, including EU policies, are common in policy studies (e.g. European-wide renewable energy targets for 2020) where these documents perform as a source of data and object of analysis.

The main themes in regard to renewable energy in general and wave energy in particular, that can be identified in the literature (and some of them appeared to be relevant for this study), include: renewable energy (wave energy) as a resource and commodity; technologies to produce and transfer energy, an innovation process surrounding the development of new renewable energy technologies; markets, regulators and main actors or stakeholders, energy economics which is central to

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[1] Policy documents in relation to renewable energy and policy discourse will be analysed in Chapter 5.
[2] Although the academic field of energy transitions is an attractive topic for further discussion and analysis, it would go beyond the aim of this dissertation to accomplish this kind of analysis.

energy policy studies; the infrastructure (e.g. facilities, transmission and distribution networks) to produce renewable energy and the services energy is needed for (electricity, heat, transport); political and social risks. Besides, the analysis of energy systems (including renewable energy) is often focused on how the elements of the system interact, fit together and change, their complementarities, lock-ins and commercialisation of technologies. A number of underpinning issues, such as environmental impact, climate change, energy security, cost of energy, demand and consumption are also discussed in relation to renewable energy agenda.

2.2.1. Renewable energy policy and energy transitions

The studies on energy systems in general and renewable energy in particular often consider policy and regulations as a macro context, a framework reflected and implemented in existing legal system and institutions. The literature refers to the institutional context and policy framework in analysing case studies, technological and energy systems or whole industries (e.g. wave or wind energy sectors). Renewable energy policy is often discussed under a more general theme of policy making for low carbon economy, energy transitions and sustainable energy futures, and innovation. There is a wide recognition of the importance of renewable energy theme and its global character.

The main questions analysed and discussed in literature in relation to renewable energy policy include policy actors and power, policy mechanisms and their implementation, decision-making process, comparison of different jurisdictions and international trends, as well as imaging of future energy scenarios. In these studies the assessment of effectiveness of policy instruments and measures in the field of renewable energy is among the key issues (e.g. market *vs.* regulation mechanisms questioning the advantages and disadvantages of one or another approach). The scholars claim to represent critical thinking in terms of practicality and efficiency using evidence-based argumentation. Recognising the complexity of the issues and the dynamic of policy change, they point to ‘failures’ and search for ‘optimal’ or ‘better’ policy and the ways for its implementation. These studies are numerous and only a few exemplifying papers on renewable energy policy in the UK will be specified below, especially those which contribute to the debate over the best ways to provide support for new energy technologies.

A few studies provide an overview of the UK renewable energy policy, analyse its historical background and technology choices (e.g. Connor, 2003; Mitchell and Connor, 2004; Pollitt, 2010). The study by Mitchell and Connor (2004) can serve as an example of retrospective analysis of the renewable energy policy in the UK providing a review of the policy during the period 1990-2003. The authors describe the main policy mechanisms (particularly, NFFO and RO), criticising renewable energy policy in the UK for a lack of clarity of goals, 'mistakes' and barriers, arguing for a number of changes and calling for 'learning' by the Government (Mitchell and Connor, 2004).

Pollitt (2010) considers the UK's renewable energy policy in the context of its overall decarbonisation and energy policies, suggesting policy changes which would be institutionally appropriate to the UK. With the focus on the electricity sector Pollitt considers renewable generation, as well as the facilitating role of electricity distribution and transmission networks. He suggests that attention should be paid to cost effectiveness of renewable energy technologies, as well as societal preferences and the available mechanisms for encouraging social acceptability which also play crucial role for effective renewable energy policy (Pollitt, 2010).

Another study of policy mechanisms for renewable energy sector in the UK is by Woodman and Mitchell (2011), where the authors analyse the effectiveness of the policy mechanisms in the UK comparing the Renewables Obligation and Feed-in Tariff. They explore the reasons for poor performance of the market mechanisms for development of renewable energy, pointing to the strategic emphasis on competition in the support mechanisms which has played a key role in limiting renewables development (Woodman and Mitchell, 2011).

The problem of cost competitiveness for renewable energy technologies is also discussed as part of a wider debate over policy mechanisms for renewable energy, e.g. wave and tidal stream power technologies (Allan et al., 2011). The analysis of Renewables Obligation mechanisms in relation to those technologies includes a comparison of the impact of the UK government support level to assistance for marine technologies in Scotland. The provisions in the UK are criticised as not sufficient to reduce the costs to a level comparable to non-renewable technologies. The analysis of government regimes and policies in other locations, e.g. Scotland, also add to the overall analysis of renewable energy policy in the UK (e.g. Johnson et. al., 2012).

As we can see, in renewable energy policy studies the main concern is often with financial mechanisms and economics of renewable energy technologies. However, the approach is changing towards system-based analysis where the whole energy system, i.e. its structure, scenarios, networks, public perception and other social dimensions of energy change, etc., is analysed in a wider context of sustainable energy futures and energy transitions.

Energy transition studies

Energy transitions literature is a distinct field where transition theory (theories of socio-technical transitions or transition management) is adopted as the dominant theoretical approach to the problem of negotiating the shift to low carbon economies. This lexis influences the ways of thinking about energy and can also be found in policy discourse, e.g. the UK Low Carbon Transition Plan 2009. Going beyond a narrow understanding of energy transitions exclusively in terms of fuel sources (e.g. from fossil fuels to renewables), the transition literature discusses social, political and economic transformations, advocating a system approach to sustainability and energy change. Consequently, more diverse topics that cover various aspects related to climate change, sustainable energy and low carbon societies can be found within the domain of energy transitions, bringing together different views and standpoints and suggesting a dialogue between different disciplines.[2] The use of an STS perspective on energy transitions, which is also represented in this literature,

[2] Although the academic field of energy transitions is an attractive topic for further discussion and analysis, it would go beyond the aim of this dissertation to accomplish this kind of analysis.

helps to build a more systematic knowledge on energy transitions offering the means to analyse them as socio-technological system transformation.[3]

Although in energy transitions literature the focus is not solely on renewable energy domain, renewable energy is considered as a key component of transitions to sustainable energy futures. For instance, Mitchell (2008) discusses renewable energy as a component of sustainable energy in the context of a wider ‘regulatory state paradigm’ and transition to sustainable energy future, arguing that renewable energy technologies do not fit in the UK political paradigm (Mitchell, 2008). The critique of markets as the only regulator (and market-oriented policy) is accompanied by call for new approaches to economics and regulation based on long-term views. Mitchell argues that intervention in support of sustainable technologies is needed, although should not preclude competitive markets. To support her argument, Mitchell uses comparison with other countries that are more successful in developing renewable energy sectors, and points to the lack of support for renewable energy in the UK, suggesting that the principles of the political paradigm constrain effective policy design. It is important that Governments provide certainty and persistence of policies, as well as reducing risk. Mitchell sees transition as a ‘system’ issue – it crosses technological, institutional, social and cultural concerns and is not bracketed solely in one of them. As such, a new way of designing policies and ‘incorporating sustainable innovation evidence’ should be adopted. It is argued that a powerful, interwoven framework is needed which would link policies, innovation, economic regulation, planning, consumption and technology issues to move to a sustainable energy economy. It will require intervention in support of these sustainable technologies within markets and within economic regulation (ibid.).

Studies of national conditions, cultures and pathways to low carbon societies provide a ground for deliberations about progression towards sustainability. Comparative analysis is often used to explore policy paradigms, political and regulatory models in different countries for energy transitions which result in different energy systems outcomes. Despite of claiming a more inclusive systems approach, the scholars

[3] See *Science as Culture*, 2013, Vol.22, No.2, Special Issue: *Science as Culture Forum on Energy Transitions*.

dealing with governance, policy and political paradigms often employ institutional approach discussing the institutional context and policy framework for energy change, and operate the same set of traditional actors – energy industry, policy makers, energy users and other 'rational market actors' (e.g. Nilsson et al., 2011, Pollitt, 2012, Kuzemko, 2013). Institutionalism, or more advanced neo-institutional approach, is used to discuss regulatory support and institutional influences (both formal and informal) for low carbon (sustainable) transitions and large-scale transformations of energy systems. Similar to energy policy studies, exploring UK policy paradigm (institutions, objectives, policies) the studies on energy transitions often focus on institutional design in the UK and the routes to achieve energy goals set by government in line with EU targets.

The attempts to reveal insights into the complexity of energy system change lead to adoption of socio-technical approach that can help to understand transitions as complex socio-technological system transformations (Miller, 2013). For instance, analysis of energy infrastructure, which is foundational to modern energy systems, is often approached from this perspective where the questions about design choices and transformation of existing arrangements are mainly in focus (Jones, 2013, Karnøe, 2012, Karnøe and Garud, 2012). Some of the studies based on socio-technical approach will be discussed in the next section of this literature review.

2.2.2. Innovation and technological development studies

New developing technology-based sectors of economy are often studied from the innovation perspective. The policy discourse in the renewable energy sector is also strongly interwoven with innovation and technological development. The analysis of the sector and related policies therefore is often based on innovation approaches among which the most common are the national system of innovation approach and the technological system approach. The first approach is often presented as the most advanced among institutional approaches to innovation (Coriat and Weinstein, 2002). It became the basis for policy development in many countries and is employed for analysis of policy mechanisms and instruments used in energy policy. The assessments of national innovation systems are based upon case studies and concentrate on nation states. A significant number of studies on innovation, including those in the field of renewable energy technologies, are based on this concept elaborated mainly by Freeman (1987), Nelson (1992) and Lundvall (1992). From this perspective, policy and financial matters are spoken about as being powerful instruments, or mechanisms, which, in turn, are seen as a framework for industry by policy-makers themselves.[4]

It is suggested that the technological system approach is useful when the focus of the enquiry is to study the competition between various ways of supplying energy (Jacobsson and Johnson, 2000). The component parts of a technological system are actors and their competence, networks and institutions, thus a variety of factors are considered including not only national institutional framework but also the maturity of a particular industry and technology characteristics. These studies focus on issues like how a new system is formed based on competence in a new technological field, involving reformed or new networks and institutions which support the new technology (Jacobsson and Johnson, 2000). Such approaches consider systems as main units for analysis, perpetuating the divide between macro, meso and micro levels of analysis, where policy and regulation are viewed as a macro context.

Drivers and barriers for UK innovation system are also often discussed in relation to technological development and technological change in renewable energy sector. For example, using the innovation system approach, Foxon et al. model the technology diffusion process through stages of technology maturity (which include R&D, demonstration, pre-commercial, supported commercial and commercial), suggesting that market penetration of renewable energy technologies was reliant upon the level of technology maturity (Foxon et al., 2005). On the basis of the analysis of ‘system failures’ in moving technologies along the innovation chain they argue for a stable and consistent policy framework represented by a ‘better mix of policy instruments’ as policy instruments varies with a phase of technology’s development (ibid.).

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[4] E.g. see Chris Huhne’s speech to the Renewable UK Conference, 26 October 2011 (the then Secretary of State for Energy and Climate Change 2010-2012) http://www.decc.gov.uk/en/content/cms/news/ch_speech_ruk/ch_speech_ruk.aspx

Discussions of innovation systems also take a form of analysis of ‘technological paths’ for new emerging technologies and creation of new industries, as for example in case of wind energy (Garud and Karnøe, 2003, Karnøe, 2012, Karnøe and Garud, 2012).

Exploring development of wind turbines, contrasting approaches from Denmark and the US in shaping technological paths for wind energy technology are discussed, and in particular, how a ‘bricolage approach’ is able to prevail over a ‘breakthrough approach’ (Garud and Karnøe, 2003). Garud and Karnøe point to the inherent disadvantages of a breakthrough approach which was employed in the US suggesting that it can ‘end up stifling micro-learning processes that allow for the mutual co-shaping of emerging technological paths to occur’ (ibid.). This means that the failure may occur not despite, but *because* of pursuit of a breakthrough by actors in the US. In contrast bricolage, preserving emerging properties, helps to move ahead ‘on the basis of inputs of actors who possess local knowledge, but through their interactions, are able to gradually transform emerging paths to higher degrees of functionality’ (ibid.). It is suggested that path creation results in accumulation of artefacts, practices, knowledge, thus for discussing technology entrepreneurship and transformation of emerging technological paths a concept of distributed agency to discuss the engagement of actors in shaping technological paths might be useful (ibid.).

In a few recent studies evolution of wind energy is explored along with political developments in Denmark and conditions for shifting valuation of wind power with a focus on how renewable (i.e. wind) energy as an emerging cluster copes with already-set energy arrangements (Karnøe, 2012, Karnøe and Garud, 2012). It is suggested that the disruptive consequences on the material arrangements of the power system involve rearrangements of socio-technical components of energy systems in order to normalise disruptions associated with wind energy, creating certain flexibility. Considering penetration of the existing network of power and its effect on the society, some scholars suggest to analyse emerging industries through a lens of path creation, argue for path creation rather than path dependence for energy systems (Karnøe, 2012).

It is apparent that these studies are closely linked with policy research: they aim to inform policy makers in support of innovation in renewable energy sector and to improve design of policy instruments needed for successful innovation. However, questions are rarely asked about how such utility is achieved.

Another category of studies on innovation and technological development in the renewable energy sector represents innovation in its practical implementation discussing technological aspects of this process in regard to particular technologies. Technological aspects of wave energy conversion are among key issues of wave energy utilisation, and form a distinct field of research, which includes hydrodynamics of wave energy absorption and control, technology design and characteristics (including modelling and testing prototypes), mooring systems, specific equipment etc. Overview of different concepts of wave energy systems and their classifications provides with an understanding of the complexity of wave energy technologies (e.g. Falcão, 2010). Studies around particular technologies (e.g. wave energy converters), as a rule, are focused on viability and efficiency of technologies (Dalton et al., 2010b; O'Connor et al., 2013; Orer and Ozdamar, 2007; Ulvin et al., 2012).

2.2.3. Public perception and resource assessment: case study approach

The theme of public perception is one of the most prominent in regard to renewable energy. Increased participation and community involvement in renewable energy developments leads to wide debates and the need to understand the nature of the controversies arisen in these cases.

Although the wind farm debate is mainly in focus, there are a number of studies discussing perception of marine energy and related infrastructure and technologies. For example, several studies consider the case of Wave Hub discussing 'stakeholder responses' to this technological project (Bailey et al., 2011; West et al., 2010; McLachlan, 2010; McLachlan, 2009). Although in general public is supportive of wave energy as economically beneficial with few adverse side-effects, it is suggested that public opinions about renewable energy are technology and location specific; it is important to understand different logics behind support and opposition positions moving away from simple NIMBYsm (i.e. ‘Not In My Back Yard’) understanding of objections (McLachlan, 2010; Bailey et al., 2011).

Exploring public attitude to offshore renewable energy projects, Bailey et al (2011) suggest that ‘non-intrusive nature and physical separation from centres of population’ (p.154) makes wave energy projects less prone to public opposition than land-based or near-shore renewable energy technologies. Concepts of risk and reward perception can be employed to explore the possible future dynamics of public attitudes towards wave energy technologies, where risk and reward perceptions are used as a broad heuristic device (Bailey et al., 2011).

Renewable energy siting controversy is also analysed using the concepts of place and technology symbolism (McLachlan, 2009; McLachlan, 2010). Arguing for multiple and diverse symbolic interpretations and logics of opposition and support, McLachlan calls for better understanding of possible reasons that stand behind them; this, in turn, can open up alternative strategies for developers and government and help to understand why renewable energy developments does or does not ‘fit’ in a particular location for different stakeholders. It is argued that not only local issues are important and considered in such controversies – public perception is seen as related to the wider context of ‘energy and climate change beliefs’ and policy (McLachlan, 2009).

Some location-specific studies on decision-making process for wave and tidal energy developments (e.g. spatial planning process) discuss it from the perspective of allocation of power and control, when the ‘pressure for development is immediate and driven by powerfully political considerations’ (Johnson et al., 2012). This represents another approach to analysing political agenda, policy and its implications through the lenses of a potential conflict over marine energy development in a particular area, which can influence future activities. For example, Johnson et al. focus on the Pentland Firth and Orkney Waters (Scotland) which is considered under present development pressure. Characterising the governance regime emerging for marine renewables as ‘strongly ‘top–down’, Johnson et al. point to the sharp divergence in the controls exercised by national and local authorities, where local authorities and communities perform only as consultees without 'powers of marine stewardship' (ibid., p.32).

Studies around wave energy also cover the physical assessment of resources and use of scientific data. Resource assessment literature is often site-specific and based on scientific representation of wave energy, wave resources and their potential, spatial and temporal characteristics, as well as discussing methodological approaches to assessment of power generation (e.g. Sierra et al., 2013; Hughes and Heap, 2010; Portilla et al., 2013; Beels et al., 2011; Carballo and Iglesias, 2012). In the UK the studies about wave energy resources and wave climate mainly consider two locations – Scotland and South-West of England which have benefited from large investments to develop test sites (e.g. Folley and Whittaker, 2009; van Nieuwkoop et al., 2013). The important feature of these studies is their practicality – it is claimed that knowledge about wave climate and resources available are essential for planning and design of wave energy projects, and as such for development and growth of the industry.

Although this set of literature fulfils an important role in the functioning of renewable energy science and policy, my contention is that some of the assumptions made in the literature could become subject of further research. For instance, it would be beneficial to pay attention to the construction of content of renewable energy projects (or facts and artefacts of renewable energy) through empirical research into practices of science, technology, as well as policy. In the second part of the literature review I will explore how STS approaches could enrich studies in renewable energy and help me to formulate the research questions concerning policy, credibility and expertise in studying a technological project in renewable energy.

2.3. Science and Technology Studies: relevant concepts and approaches

It is suggested that 'sociology is and always has been preoccupied with both technology and science' (Law, 2008), and they can be seen as a core of the social (ibid.). The emergence of a distinct new discipline with an explicit focus on science and technology can be traced back to 1970. STS started as a discipline that explored epistemic practices of science by means of contemporary and historical empirical case studies, sometimes descriptively and sometimes critically. Then it added to its topics by including technology, and added to its intellectual resources by including approaches borrowed from the history of technology and history of science, philosophy of science and technology, anthropology, feminism, semiotics, post-colonialism, and post-structuralism. Initially named as Science, Technology and Society, it has run under a number of labels including ‘science studies’, ‘science and technology studies’, ‘the sociology of scientific knowledge’, and ‘social studies of science and technology’ (ibid.). It is recognised that studies of scientific practices and the production and use of technologies have generated broader understandings about how knowledge is generated and distributed, about the social and organisational effects of new technologies, and about the nature and sources of expertise (Woolgar et al, 2009). Subsequently, it moved from its initial preoccupation with science and technology to explore other empirical areas (health care, medicine, genomics), and STS-related approaches can be found on studies of ‘nature’, spatialities, markets, information technologies, organisational behaviour etc. STS has become an interdisciplinary field comprising social studies of science and technology in various aspects, and including different analytical perspectives, such as relativism and social constructivism, social shaping, actor-network theory and reflexivity (ibid.). STS can be thought about as a vast, complex, multidisciplinary enterprise, a ‘set of sensibilities’ rather than a unitary set of approaches and methods (ibid.).

The ideas developed within STS and most relevant to my thesis are that social and material cannot be distinguished and there is no sense in doing so, although such distinctions are made in practice and it is important for STS to understand how that takes place. Moreover, the ‘social’ has disappeared as a basic analytical category; the human/non-human distinction is seen as a consequence or effect of relations; the attempts to measure or scale the ‘micro’ and ‘macro’ are similarly relational effect (ibid.). In STS the role of case studies is extremely important, as STS develops its theoretical arguments through empirical cases. This puts a question mark over distinction between empirical research and social theory in STS (Law, 2008). The next section will begin to critically discuss key concepts in sociology of technology.

2.3.1. Sociology of technology

As noted earlier, sociology of technology, or social studies of technology, derives from a discipline called sociology of scientific knowledge (SSK), or sociology of science, and as such is largely informed by concepts and approaches (‘explanatory formula’ Woolgar, 1991) of SSK. The main idea for sociology of science is to empirically look at the actual content of scientific theories, concepts and experiments as the subject of sociological analysis (Pinch and Bijker, 1989). The social constructivist view prevails within the sociology of science, which means that all knowledge claims are treated as being socially constructed and the explanation should be sought in the domain of the social world rather than in the natural world (ibid.), and when the very distinction is rendered problematic. The general claim is that there is nothing epistemologically special about the nature of scientific knowledge, and it is a sociological task to explain the success or failures of certain knowledge cultures (ibid.). This approach led to the development of a programme of empirical research which helps to understand the process of construction of scientific knowledge in the variety of contexts. One example is case studies in form of laboratory ethnography, the first of which was *Laboratory Life: The Construction of Scientific Facts* by Bruno Latour and Steve Woolgar (1979/1986) which represents an anthropological approach to science culture and social world of a laboratory based on observations of how scientific work is conducted.

Later, sociology of scientific knowledge was extended into the sphere of technology. This stance is represented by work of T.Pinch, W.Bijker, T.Hughes, M.Callon, B.Latour, S.Woolgar, J.Law and some others. As Pinch and Bijker (1989) suggested, a constructivist view of science and technology fits well with the conception of the science-technology relationship. Simplistic models and generalisations (‘science discovers and technology applies’) do not satisfy researchers, and the change of thinking was based on understanding it as ‘symbiotic relationship’ where science and technology are intermixed (Pinch and Bijker, 1989, p.20-21; Layton, 1977; Barnes, 1982). It is argued, that from the systems point of view the distinctions tend to fade (Hughes, 1989). Moreover, it is claimed that the boundary between science and technology is seen as a matter for social negotiation and represents no underlying distinction, as both are socially constructed cultures which draw on the resources of the other (Pinch and Bijker, 1989). As such, ‘good historical, philosophical and strategic reasons’ can be cited for the turn to technology ‘being of the greatest significance both in terms of social studies and the impact that the field may have on other areas’ (Pinch, 1993, p.520).

Nevertheless, the move from sociology of scientific knowledge (SSK) to social study of technology (SST) provoked debates in literature about how strategic value of SSK is affected by the move to SST, what is gained or lost by the turn to technology in social studies of science, and what this move reveals about the rhetorical structure of SSK (e.g. Woolgar, 1991). It is suggested that whereas SSK has been generally concerned with ‘pure’ academic research with ‘potential for reevaluating fundamental assumptions of modern thought’, SST has the rhetorical appeal of potential utility (Woolgar, 1991), and the turn to technology was sometimes viewed as ‘intellectual slumming’ (Winner, 1993, p. 365 about Woolgar, 1991). Although SST was seen as a new field to apply powerful ‘research apparatus’ of SSK, some authors (e.g. Woolgar, 1991) argue against establishing SSK as an explanatory formula or a tool to be applied as it can in turn affect the theoretical significance of SSK. Critics like Woolgar (1991) noted that the scholars were interested in demonstrating the possibility of the move to SST and establishing constructivist perspective to be applied to technology rather than to account for the move explaining why it became apparent.

Some scholars disagree with Woolgar’s vision of the move from SSK to SST where the turn to technology is seen as a formulaic application of SSK. They call the move to technology that shares a common SSK formula a ‘myth’ or a ‘fiction’ (see, e.g., Pinch, 1993). Engaging in polemics with Woolgar, Pinch points to a number of different forms of SSK with a variety of analytical methods, arguing that certain approaches, that also renounce sociological reductionism (e.g. actor-network theory) do not make distinction between science and technology, but rather referring to *technoscience* (Pinch, 1993). He argues, that for many scholars and practitioners of science and technology there is no difference as ‘science and technology both embody the laws of nature and warrant equal attention’ (ibid., p.520).

The ideas developed in the history and sociology of science are used in a sociological analysis of technology, and a whole body of sociology was launched where social constructivist view was dominant, demonstrating how the constructed character of the content of some technological artifacts might be approached empirically (Pinch and Bijker, 1989). The assumption that technology, as well as science, can be understood as a social or even political construct is one of the concepts put forward in technology studies. Social constructivism offers guidance for doing case studies of technological innovation and attempts to provide empirical models for technological change emphasising contingency and choice rather than forces of necessity in the history of technology (Winner, 1993).

It is widely recognised that social constructivism has become a prevailing intellectual path in technology studies. Although the basic disposition is fairly consistent, constructivism is not an ‘entirely unified viewpoint’ (Winner, 1993, p.366). Different approaches in sociology of technology can be found in STS literature. Most of them can be seen as a reaction against technological determinism; they are based on the idea that ‘technology’ comprises much more than just machines including social arrangements (Grint and Woolgar, 1997), and as a result attempt to place technology in wider context. Three of them are presented by Pinch and Bijker, Hughes, and Callon in *The social construction of technological systems* (1989), where the authors advocate the integrated study of society and technology. They outline a research programme for studying the development of technological artifacts and systems which can contribute to ‘a greater understanding of the social processes involved in technological development while respecting the seamless web character of technology and society’ (p.10).

The first approach, social constructivism in its classic form, is based on the assumption that ‘artifacts and practices are best seen as the ‘constructions of individuals or collectives that belong to social groups’; different groups have different views of the proper structure of artifacts; the process of stabilisation (or ‘closure’) depends on the capacity of social groups to mobilise resources according to their social interests (Law, 1989, p.111).

This approach is represented, for example, by the work of Pinch and Bijker (1989) who outlined an integrated approach to the empirical study of science and technology – the social construction of technology (SCOT), using analogy with the one developed in the sociology of scientific knowledge for studying the ‘hard’ sciences – the empirical programme of relativism (EPOR) which is a well-established programme representing the efforts ‘to understand the content of the natural sciences in terms of social construction’ (Pinch and Bijker, 1989, p.27) with a focus on scientific controversy and contemporary scientific development. It was suggested to employ the same methods and concepts to study technological artifacts and identify the same stages in their evolution (interpretative flexibility, closure and stabilisation, the relation to the wider context). The developmental process of a technological artefact for this programme is described as an alteration of variation and selection explaining the evolution of technological change. Pinch and Bijker (1989) operate a ‘multidirectional’ model which demonstrates that the ‘successful’ stages in the development are not the only possible ones and this scenario is not inevitable. They use the example of the bicycle and compare a multidirectional view of the developmental process of the Penny Farthing bicycle with the traditional quasi-linear view, demonstrating that if a multidirectional model is adopted it is possible to question the survival of some variants and failure of others. In SCOT the first stage – interpretive flexibility is the demonstration that technological artifacts are culturally constructed and interpreted and that there is flexibility in how artifacts are designed. The authors use different social groups with sometimes controversial interests to illustrate this process. The second stage in SCOT is stabilisation of an artefact through the closure mechanism (rhetorical closure or closure by redefinition of the problem). And finally, the third stage of this research programme is ‘to relate the content of a technological artefact to the wider socio-political milieu’ (ibid., p.46) based on the claim that there is a relationship between the actual content of technology and the sociocultural and political context, as the norms and values of different social groups are shaped by this context.

Bijker (1989) elaborated these ideas further and introduced a concept of a technological frame (which is interlinked with Hughes’s technological momentum), and a concept of inclusion. He also outlines a typology of different sorts of technological change. Three situations were distinguished simplifying the description of the ‘seamless web’ and bringing some order: no dominant technological frame (in situation when no one social group is dominant), one technological frame (a dominance of one social group), and several dominant technological frames (Bijker, 1989). The differing degree of inclusion of actors also helps to explain the social processes underpinning the construction of artifacts and varying degrees of interaction within one technological frame.

Some sound critique of this approach and its application can be found in literature. For example, Woolgar (1991) criticises Pinch and Bijker for being ‘more concerned to establish that the social constructivist perspective can be applied to technology than to explain why this possibility became apparent’ (Woolgar, 1991, p.21). Moreover, the very concept of relevant social groups who are engaged in process of defining technical problems is criticised for attending mainly the needs and problems of powerful groups (Winner, 1993). Winner raises questions about who decide on defining relevant social actors and social interests, as well as about groups who are affected by the result of technological change but have no voice or groups that are, for example, deliberately excluded (ibid.). For Winner, the methodological principle of interpretive flexibility works well in cases where social consensus is achievable but can be problematic in situations when there are serious disagreements about technology or its use (ibid.). Klein and Kleiman (2002) join forces with Winner pointing to the deficiencies in a discussion of groups’ capacity of power (power asymmetry) (Klein and Kleinman, 2002). Exploring some methodological and explanatory difficulties that arise with SCOT approach, they also suggest considering structural factors in the social shaping of technological development. Grint and Woolgar (1997) point to the limitations that SCOT place upon the social aspects of technology that undermine the significance of actors’ interpretations and uses of technology. They emphasise that technology is an unstable and indeterminate object whose significance is negotiated and interpreted by social actors (Grint and Woolgar, 1997).

Another approach to study of technology comes from the history of technology and insists on understanding of technological innovation and stabilisation in terms of a systems metaphor which implies the relevance of social, economic, political, and scientific factors which are interrelated and potentially pliable; the innovators here are seen as system builders (Law, 1989). The histories of a number of technological systems are presented by Hughes (1989) in *The evolution of large technological systems*, where the author operated with the concept of ‘technological system’ which is seen as containing ‘messy, complex, problem-solving components’ including physical artifacts, organisations, scientific components, legislative artifacts which are socially constructed and society shaping (p.51). The system metaphor based on relational logic is central to Hughes’ picture (Law, 2008). It implies that elements in a system are significant and achieve their form and character only in relation to one another (ibid.). Such systemic approach to technology evolution allows developing an understanding of invention, development and innovation phases for technological systems. The concepts of reverse salient, momentum and technological style were also specified for evolving systems.

MacKenzie (1989) applies technological systems approach developed by Hughes for investigation of ballistic missile accuracy and the process of its technological development. He draws attention to such aspects of this approach as simultaneous engineering of technological, economic and political matters for system being successful; systems and networks are not taken as given and unproblematic; there is no an absolute distinction between the micro and the macro seeing the notion of reverse salient and critical problem as a key bridge between them. Justifying the use of the term ‘system’, MacKenzie (1989) emphasises that it should not be taken to imply stability and lack of conflict as there is always the potential for their dissociation into component parts; the stability of systems is uncertain in the face of potentially hostile forces, both social and natural. Technological system approach, as it is understood by MacKenzie, closely resembles network approach advocated by Law and Callon, in which the implicit refusal of boundaries between the micro and the micro, technical and social become more explicit.

Although these approaches have much in common (the technology is not fixed by nature alone and technological stabilisation can be understood only if artifacts are seen as interrelated with nontechnological and social factors), they slightly diverge in question about the relationship between technological and social: social constructivists privilege the social in the search for explanatory simplicity whereas the adherents of systems approach do not see the social as especially privileged (Law, 1989), so do not ANT scholars who suggest a network approach to studies of technology, technical change and innovation.

Another approach in STS developed mainly by scholars at the Centre of Sociology of Innovation (CSI) at the School of Mines in Paris is known as actor-network theory. The founders of this approach are M.Akrish, M.Callon and B.Latour, but also J.Law who was based at Lancaster University Sociology Department during the time when the approach was developed.

The pioneering study by Callon (1989) of the electrical vehicle in France demonstrated that ‘almost everything is negotiable: what is certain and what is not; who is scientist and who is technologist; what is technological and what is social; and who can participate in the controversy’ (Pinch and Bijker, 1989, p.26). He argues that technical, scientific, social, economic, political considerations present from the beginning of innovation process and deeply interwoven. The concept of heterogeneous associations is the key in actor network introduced by Callon. He uses the notions of simplification and juxtaposition to explain the dynamic of the electrical vehicle case (Callon, 1989). Callon sees it as a new methodological tool and argues that actor network approach is applicable to the whole process of technological development from invention phase to the gradual institualisation of the market for new technology because ‘it encompasses and describes not only alliances and interactions that occur at a given time but also any changes and developments that occur subsequently’ (ibid., p.100). This approach leads to a new interpretation of the dynamics of technology and can be seen as a step further from systems analysis which stresses ‘all the connections linking ‘inside’ and ‘outside’ the system’ but presupposes that a distinction can be made between the system itself and its environment (ibid., p.101).

Law (1989) argues that there are two main approaches in social studies of technology (which were explained earlier), and describes his own position as network approach joining forces with Callon. As historians who apply system-building perspective (e.g. Hughes, 1989), Law does not see social as a prevailing component *a priori*, but makes an emphasis on conflict within network approach adding that systems are built from indifferent or hostile elements through a struggle. He suggests that the artefact can be seen as a network of juxtaposed components and justifies two methodological principles: a concept of 'generalised symmetry' and that of 'reciprocal definition'. The former implies that 'the same type of analysis should be made for all components in a system whether these components are human or not'; the latter means that 'actors are those entities that exert detectable influence on others' (Law, 1989, p.132). He considers the historical case of Portuguese maritime expansion to illustrate how 'heterogeneous engineers' seek to create 'a relatively stable set of associated entities that achieved relatively durability' and handle natural and social forces indifferently to reach an appropriate form of closure (ibid., p.128). Seeing technology as a set of channelled forces and associated entities, Law (1989) emphasises the importance of a system, or network, to be able to assimilate potentially hostile external forces to become relatively stable and not fall apart. Using system logic, ANT considers all elements – technologies, 'natural' phenomena, documents, etc. – as relational effects being done in interaction (Law, 2008). According to Law (2008), ANT approach is based on general assumptions that 'Everything is uncertain. Everything is relational. And nothing is foundational'. It is claimed that actor-network theory cannot be really counted as a form of sociology, as it doesn't provide a strong social explanations for the origin of phenomena or social critique. Instead, it asks how they occur and arrange themselves, how social, technical, documentary, natural, human etc. materials get themselves done in all their heterogeneity for a particular moment in particular location; this allows understanding ANT as a version of post-structuralism (Law, 2008).[5]

For Grint and Woolgar, actor-network theory is similar to socio-technical alignment approach but with the focus upon the practical constructions of alignments between social and technical aspects, not upon the results (Grint and Woolgar, 1997). Their criticism of ANT, which positions itself as anti-determinism approach, is based on three main arguments: it is not clear where the boundaries of a network lie and which version of it is definitive; the insistence upon the symmetry gives too much ground to

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[5] Actor-network theory will be discussed in more detail in the next section of literature review 'ANT as a theoretical resource'.

realist and technological determinist accounts; and the most important is that in some cases ANT scholars rely on definitive accounts of the properties of elements in the network (ibid.). To illustrate the last argument Grint and Woolgar refer to Callon's study of an electrical vehicle project in France in which, describing the parts played by different elements of the evolving network, Callon suggests that the break-up of the network is in part due to a particular property of the catalysts (although following constructivist logic it should be questioned like other aspects of network construction). So Grint and Woolgar see it as an evidence of residual technicism in ANT, although admitting its distinct virtue of 'pointing to the possibility of an understanding of the machine which does not depend on the presence of a god within' (ibid., p.31). They also suggest, that if ANT is viewed as a redescription rather than causal type of explanation of technological development (which needs specifications of the nature and capacity of the network's elements), it does not demand assigning inherent characteristics to elements in the network or to any explanans (ibid.).

The discussion that was produced in debate between SSK and SST developing various approaches to technology remain quite abstract. In order to understand better the relationship between social and technical we need to unpack the social in terms of culture and politics.

To sum up this overview of the literature in the field of sociology of technology, it is worth to mention critical views on SST that can also help to understand the strong and weak points of the approaches discussed above and to make choice about the way of thinking about technology.

The value of social constructivism, which is in the core of sociology of technology, was critically assessed and debated in literature. For example, Winner criticises social constructivist approach for the narrowness of its perspective with a focus on the origins and dynamics of technical innovation and 'an almost total disregard for the social consequences of technical choice' (Winner, 1993, p.368). He points to the lack of critical thinking as this approach does not provide 'solid, systematic standpoint or core of moral concerns' that would let to assess patterns of technological development and does not help to address larger questions about technology and human well-being (Winner, 1993, p.374).

Most of recent approaches in STS establish themselves as opposite to technological determinism theory. Technologically determinist theories, which underestimate the relevance of human will and claim technology as a determining force of history, are seen as illusive in social science today. Nevertheless, according to Grint and Woolgar (1997), many theories of technology still have certain elements of ‘technicism’ which means that that the capacity of technology is not seen as ‘analytically problematic’. They refer to the idea of ‘technological system’ which is often used in sociology of technology. It implies the inclusion of social arrangements surrounding technology, so ‘machines can only be understood in terms of their use’ (Grint and Woolgar, 1997, p.13). The criticism is based on the argument that in the centre of a technological system there is still a machine. They assume that the social shaping approach, derived from the sociology of scientific knowledge, reflects struggle with a dualism between ‘technology’ and ‘the social’, but again might be seen as just one more variation of technicism (ibid.). The common aim of these approaches is to open the black boxes of technology and the content of technology for sociological analysis, although it is not clear how far such arguments can go (ibid.). Trying to avoid the impression that either the technical or the social has a discrete impact, Grint and Woolgar suggest anti-essentialism as a variant of the socially constructed technology approach and as an alternative perspective to technicism (essentialism) where the boundaries between the social and the technical are part of the phenomenon to be investigated (ibid.).

Despite of some criticism, sociology of technology is a growing field and is recognised as a significant inalienable part of Science and Technology Studies discipline. It is worth to note that in recent years STS has been subject to various transformations and undergone significant expansion. It has moved beyond its traditional topics as scientific laboratories or development of technologies and technological systems and has been appropriated within new contexts, including management studies and business schools (Woolgar et al, 2009).

Technology as a cultural concept

The construal of technology as object of social studies poses a question about its meaning and character, as well as how to approach technology as object of inquiry. Meanings of technology do not exist detached from the society, its culture and institutions, and assemblages of technologies and humans that have been already built (Pinch, 2010, p.80).

In the literature it is suggested that three layers of the word 'technology' can be distinguished: a physical object or artefact (e.g. a bicycle), activities or processes (e.g. steel making) and what people know and what they do (i.e. 'know-how' for designing a bicycle) (Bijker et al, 1989). They can also be referred as artefacts, practice and knowledge (Hardy, 2010) or, as suggested by Garud and Rappa (1994), as artefacts, evaluation routines and beliefs.

The definition of technology as artefacts highlights its physical properties, such as dimensional shape and materials of construction, and functional characteristics, i.e. its use (ibid.). From the material perspective, technology can be viewed as 'an identifiable, relatively durable entity, a physically, economically, politically, and socially organized phenomenon in space-time' (Orlikowski, 2000, p.408). Some technologies have specific features which might not be common for other types of artefacts and might be contested, e.g. embeddedness into other structures and social arrangements, embodiment of standards and construction on an installed base of infrastructure (Star, 1999), or invisibility of some pieces of contested infrastructure, such as invisible dog fences or an invisible wall known in Jewish Law as an eruv (Pinch, 2010).

The understanding of technology as practice or as a set of evaluation routines rejects the idea that properties are intrinsic to artefacts; rather they are construed through human-technology relations (Hardy, 2010). In this view technology manifests itself in recurrent social practices (Garud and Rappa, 1994; Orlikowski, 2000). It involves 'repeatedly experienced, personally ordered and edited' versions of a technological artefact which can be experienced differently by different individuals (Orlikowski, 2000, p.408). The practice approach also requires an understanding of how these practices emerge (Garud and Rappa, 1994). The third definition of technology is based on its representation as knowledge (ibid.). This approach is important for understanding technology in the making which might include existent technology and what individuals believe is possible (ibid.). To understand technology from this perspective requires an appreciation of how beliefs form over time (ibid.). In some cases it might be useful to interpret beliefs associated with technology in terms of technologies acquiring symbolic meaning as, for example, in cases of particular technological programmes, such as the Internet (Wyatt et al, 2002), nuclear energy (Schmid, 2005) and renewable energy (McLachlan, 2010). Certain practices can be formed to support, maintain and enhance symbolic capital of particular technology.

It can be suggested that that different facets of technology being useful in and of itself mutually shape each other and ‘form the basis for unravelling the path-creation processes that unfold during the genesis of a technology’ (Garud and Rappa, 1994, p.357).

Understandings of technologies are inseparable from the means to produce such understandings, which arguably offers opportunity to learn more about technology in contemporary society.

Exploring the way in which technology was conceptualised as object, Woolgar came to suggestion to consider technology as text providing reflexive interpretation and recovering epistemological significance that was, in his view, lost in move from SSK to SST (Woolgar, 1991). It is suggested that the ‘instrumental reading’ of technology as text emphasises the interpretive flexibility of the capacity of technology: ‘It is the reader who write the text of technology’ (ibid., p.37). As an example of instrumental reading of technology as text Woolgar refers to Winner’s arguments about political properties of some artefacts (Winner, 1980). According to the ‘reflexive version’ of technology as text all versions or descriptions of technology be treated as granted equal authority with other outcome of textual production and interpretation (ibid.). A move from the discussion of whether or not artefacts have politics to interpretivist reading of technology as text (interpretivist response) emphasises indefiniteness of attributes of technology (e.g. capacity or character) and poses a question of how some technology texts appear more persuasive that others (Woolgar, 1991). The study of the ways in which technology texts are written and read is also a part of interpretivist response suggested by the notion of technology as text.[6]

This approach supported and shared by other scholars, e.g. Hardy (2010) stresses that 'there is no a priori reason why technology cannot be considered as text' (ibid., p.249). Technology is textual in a sense that it allows multiple readings by different people, and different discourses construct the same technology in different ways (ibid.). Hardy examines the idea that technologies can be treated as texts in relation to three dimensions of technology (views of technology), i.e. as knowledge, practice and artefact, suggesting that technology as knowledge is particularly amenable to textualisation (Hardy, 2010). It is argued that conceptualising technology as text makes it possible to extend discourse analytic methods to physical artefacts, and generally to open up studies of technology to greater use of discourse analysis based on systematic examination of bodies of texts (ibid.).

The politics of technology

The vast body of empirical research in STS suggests that reading of technology can be disputed. Political processes of negotiation and contestation surrounding technology come into focus when discussing technology and society relationship and cultural meaning of technology. Hence, another aspect of technology widely debated in STS literature is political character of technology and its ambivalence. The idea of political qualities of artefacts embodying specific forms of power and authority is one of the most provocative aspects of debate around material form and social content of technology (Winner, 1980).

The attempt to interpret technical artefacts in political language, according to Winner (1980), comes from the critics of large-scale high-technology systems. In the paper *Do Artifacts Have Politics?* (1980) the starting point is that technical systems are 'deeply interwoven in the conditions of modern politics' (Winner, 1980, p.122). Nevertheless, he is critical about the idea of ultimate importance of the social and economic system in which technology is embedded. This idea is a central premise of

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[6] This is also important to bear in mind for discussion of credibility in the next section.

the social determination of technology, an antidote to technological determinism theory. But, according to Winner (1980), in this theory 'technical *things* do not matter at all' (p.122) and all attention is focused on revealing the social origins of a technological change. He offers other ways in which technologies can have political properties.

Winner (1980) argues for a theory of technological politics, which he sees as a complement to social determinism theories. This perspective does not reduce the explanations exclusively to social forces but pays attention to the meaning and characteristics of technical objects identifying 'certain technologies as political phenomena in their own right'. (Winner, 1980, p.123)

To illustrate his argument, Winner (1980) outlines two varieties of interpretation for political qualities of artefacts. First, he demonstrates how specific features in the design or system arrangements can establish patterns of power and authority. As one of the examples he uses the bridge in New York designed by Robert Moses, arguing that its low-hanging overpasses 'were deliberately designed to achieve a particular social effect' – to discourage low-income groups who use buses to visit Jones Beach (embodying social inequality). Winner (1980) suggests that technical objects/technologies can be seen as ways of ordering human activities. And if at the time of making a decision about the existence of a particular technology (about the initial commitments) the choice is bigger, later 'choices tend to become strongly fixed in material equipment, economic investment, and social habit', and thus reducing the original flexibility. For Winner (1980) technical arrangements can be viewed as forms of order, and in this sense technological innovation can be compared to legislative acts as they also can establish frameworks creating public order and imposing rules on humans. Beside this strong 'design-version' of 'artefacts-have-politics' Winner uses other examples of the power of artefacts which are softer versions of such determinism (Joerges, 1999).

Second, Winner (1980) reflexes on the argument that 'some technologies by their nature political in a specific way' and need special patterns of power and authority. Exploring the issue of authority and technical practice he makes an attempt to link the properties of certain technologies with institutionalised patterns of power and authority, considering so-called ‘inherently political technologies’: ‘certain technologies do not allow such flexibility, and that to choose them is to choose a particular form of political life’ (Winner, 1980, p.128). According to Winner, authoritarian and democratic, certain technologies correspond to certain political system and require particular social conditions, e.g. nuclear power requires more authoritarian governance while solar energy is more compatible with democratic egalitarian society. Thus, choosing a technology we are making a political decision.

Nevertheless, Winner’s doctrine was criticised, especially his ‘design-version’ of ‘artefacts-have-politics’ (Woolgar, 1991, Joerges, 1999, Woolgar and Cooper, 1999). Investigating in detail Winner’s programme, Joerges (1999) compares it to Latour’s version of artefacts being political. He founds that for Latour the power of things lies in their associations rather in themselves; intention and design are not central, it is more important how things are networked with others. Further Joerges (1999) joins forces with Woolgar referring to his paper *The Turn to Technology in Social Studies of Science* (1991) where the author criticises Winner’s position for ‘rational’ connection between the revealed consequences and designers’ intentions and for ignoring that the effect of technology frequently diverge from the intended effects (Woolgar, 1991). Joerges (1999) offers another interpretation of Moses-story exploring in depth his biography and evidences for this case. Scrutinising this engineering discourses, Joerges (1999) argues that ‘Moses could hardly have let buses on his parkways, even if he had wanted differently’ because buses and other commercial vehicles were not allowed on parkways anywhere in the country, so Moses did nothing different from other parkways. He refers to the allegory of Chinese Whispers and blames Winner for presenting Robert Moses as ‘the power-seeking anti-democratic scapegoat for the crimes of this culture’, when in reality Moses was ‘the aesthete and nature politician’ (Joerges, 1999). Therefore, the question Joerges is trying to answer is why parables such as Moses-story are taken up easily by others and used variously for teaching and research? The answer is, according to Joerges, that this example in itself is a well constructed artefact, which has elegant theoretical form and interpretive flexibility, combined with a political-moral message.

For Woolgar, the dependence of Winner's stories on the outcome of technologies, which is unproblematically nominated as an effect of those technologies, seems contentious (Woolgar, 1991). Woolgar also criticises Winner's argument regarding inherently political qualities of some technologies for definite version of their capacity or effects, which actually can be contingent and contestable versions and need to be investigated as part of a phenomena (ibid.). In response to Woolgar's critique, another STS scholar, Trevor Pinch recognising rich interpretative contexts and the variety of interpretations, notes at the same time that in particular contexts (e.g. political) it still would be possible to stress that artifacts have politics (Pinch, 1993). Winner also replied to Wollgar calling for going beyond 'value neutrality' in situations of making choices about technology. Although a variety of points of view presumably exist, Winner suggests to take a stand on choices to develop or limit technologies, and it would be 'politically naive' to avoid certain conclusions in some circumstances (Winner, 1993, p.374). Moreover, he criticises social constructivist approach in general for avoiding moral concerns and solid systematic standpoint to oppose certain patterns of technological development. Interestingly, that later Woollgar and Cooper (1999) challenge the Winner's story of Moses bridges seeing Winner's iconic exemplar as 'urban legend' and the story ('Winner's bridges') as 'artefacts constructed with the intention of not letting certain arguments past' (Woolgar and Cooper, 1999, p.444).

The debates in STS concerning the nature of technology have opened up a rich set of avenues for empirical studies of technology, including relevant actors involved, politics, intentions and outcomes, as well as reinterpretations of those.

2.3.2. From credibility of scientific facts to credibility of technology

One of the focal points of the debate concerning transition from SSK to SST seems to be the attempts to translate understandings of credibility of scientific facts to credibility of technical objects. It is not a task of this chapter to provide an exhaustive overview of the construction of credibility in science (I will only limit discussion to a couple of examples). Rather I will focus on how the most influential approaches in SSK give rise to analyses of credibility of technology.

Different ways to approach credibility in STS literature reflects the structure of STS discipline – credibility of scientific facts, or 'hard' science, and credibility of technology. Often these studies have a form of historical ethnography and are built on empirical cases. Several of them will be considered in this section.

Since emergence of STS in 1970s credibility is analysed as an outcome of social and cultural practices and is recognised as a fundamental topic for the social studies of science. Moreover, it is claimed that it is 'the only topic' as any proposition in science has to win credibility (Shapin, 1995, p.258). As such, the study of credibility became coextensive with the study of scientific knowledge (ibid.).

Shaping argues that it is not a notion of 'philosophical Truth' that is in question but rather a notion of 'truthfulness' which stands for an 'adequate assurance' about the case, or a 'moral certainty' (ibid., p.259). The procedures for establishing truthfulness are undeveloped and not formalised; perhaps, as Shapin suggests, they are not formalisable (ibid.).

It is suggested that there should not be a theory of how credibility is achieved. Shapin argues that there is no limit to the considerations that might be relevant to establishing credibility – any aspect of the scene may prove to be relevant and 'the relevance of *nothing* can be ruled out in advance of empirical inquiry' (ibid., pp.260-261). Therefore the analyst of science needs to stay open to all kind of considerations, including the plausibility of claims, the reliability of procedures used to produce a claim, multiplicity and directedness of testimony, how accessible and replicable phenomena are, personal reputation and power of claimants, their expertise and other personal characteristics, the manner in which claims are delivered, reputation of the platform from which they speak, etc. (ibid.). It was noted that credibility-predicaments may vary according to the nature of claims and relationship between claimants and those who is meant to believe. Thus, for study of credibility it is important to specify the credibility of what is explored and who is a recipient of a description or explanation (ibid., p.261).

The approaches to credibility in STS were developed on both empirical (ethnographic) studies and historical investigations. One of the most prominent examples of ethnographic studies is *Laboratory Life: The Construction of Scientific*

Facts by Bruno Latour and Steve Woolgar (1979/1986) and an example of a historical study is the analysis of controversy between Hobbes and Boyle at the wake of the experimental era in science in the 18th century (Shapin and Schaffer, 1985).

Starting with discussion of construction of credibility in science, it is worth to pay attention to a few influential studies that offer approaches to analysis of scientific practices and pose questions about production of scientific knowledge and credibility of claims in science[7].

For example, Latour and Woolgar in their laboratory study present an anthropological view on laboratory science discussing the culture of scientists. The study is based on observations on how scientific work is conducted in one particular laboratory, including the complex relationship between the routine lab practices, the publication of papers, prestige, research finances and other elements of laboratory life. The authors demonstrate how the approach to study a ‘hard fact’ as a network effect can help to sociologically deconstruct it. The key theme of this volume is the idea of credibility and various definitions for credit. The authors claim that credibility capital is a driving motive for scientists. They show the sense in which credit and reward are important to them suggesting that to denote credit as reward scientists use the notion of credibility as recognition of merit. For Latour and Woolgar the notion of credibility, besides denoting credit as a reward, is associated with ‘belief, power and business activity’ (Latour and Woolgar, 1986, p.194). The notion of credit is used to link together different aspects of laboratory activity in order to account for the construction of individual careers without separating the resulting individual from the activity of fact construction in the course of which he is created; credibility of scientists and their results are seen as identical. Developing this idea further, Latour and Woolgar suggest that the notion of cycles of credit that makes it unnecessary to specify ‘the ultimate motivation behind the social activity which is observed’, leading to more general conclusion that ‘it is the formation of an endless cycle which is responsible for the extraordinary success of science’ (ibid., p.231).

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[7] Historic studies have largely felt beyond the scope of this literature review due to need to analyse more contemporary developments.

Another empirical study of modern scientific practice, and in particular, production of scientific knowledge through observation practices, is the one by Trevor Pinch (1985) T*owards an Analysis of Scientific Observation: The Externality and Evidential Significance of Observational Reports in Physics.* The analysis is drawn from two cases examined by the author - the detection of solar neutrinos and measurements of solar oblateness, where the problem of acceptance of the observation results was explored. The starting point for analysis is that the reliability of experimental practices and assumptions that went into observation process is highly important. For this branch of physics the process of observation is 'highly mediated by experimental manipulations, practices and processes of interpretation' (Pinch, 1985, p.7). Pinch refers to the chain of interpretations as the 'externalization of observation' (ibid., p.8). Another concept used by Pinch is the 'evidential context' which is necessary to understand the purpose of observation (e.g. a body of knowledge, a theory, a hypothesis, a set of observations, etc.). Both concepts are used to 'enable certain features of scientific observation to be compared and contrasted' (ibid., p.28). The problem with highly externalised observation is that different reports with different levels of externality are available from any single experiment, and they might be recognised significant in different evidential contexts.

One important conclusion made in this study describes the experimenter's dilemma which suggests that reports of high externality in view of their high evidential specificity are more risky (i.e. can be recognised as false) but have a greater chance of making a contribution to the wider corpus of knowledge, while reports of low externality are more likely to be accepted (i.e. less risky) but also sacrifice profundity and are trivial. So the choice is whether 'to go for a safe low-level report which stands little chance of being challenged, or to be more bold and risk a high-level report which emphasizes the profundity of the observations for some specific evidential context' (ibid., p.24). Pinch points to a tension between the need for profundity and the need for veracity as reports of low externality corresponds to maximum veracity, while reports of high externality correspond to maximum theoretical significance. As such, Pinch offered 'a framework for describing the moral economy of risk and reward' in particular scientific community (Shapin, 1995, p.265).

Experimental controversies reveal the process of making and unmaking observational reports and the process of settling the appropriate evidential context for such reports. Discussing the settling of the evidential context, Pinch also refers to the process of ‘black-boxing’ which involves ‘the settling of an evidential context for the instrument’ (Pinch, 1985, p.30). This means that every use of an instrument reproduces the evidential context. For Pinch the establishment of evidential context with black-boxed instruments also implies the establishment of social relations and can help to understand the success and stability of science.

As this example illustrates, scientists often deal with so-called ‘authorised’ objects which are of interest to professional community, and such monopoly of ownership is guaranteed by the nature of scientific practice (Shapin, 1985). When discussion of credibility shifts to the public domain, the idea of ‘modulators of credibility’ can help to understand considerations that shape credibility of scientists or experts claims among the public (ibid.). According to Shapin, this might include the relationship between scientific accounts and social and cultural beliefs and social values, the forms of accessibility of science to the public, and the extent of expert consensus. In addition to that, Shapin uses the notion of ‘*vectors* of credibility’ suggesting that the credibility-economies can obtain along different vectors (e.g. the economy of credibility internal to scientific practices and between scientific and technical groups in modern differentiated societies), but most attention is paid to the vector which can be named ‘the *public* credibility of expert claims’ (ibid., p.269).

Moving to the question of credibility in technology studies it is important to note that the problem of credibility of technology usually comes into focus when technologies have high societal importance, and/or associated with high risks and possible hazards, and often depends on public funding. As such, discussion of credibility of technology often goes beyond a small group of specialists (e.g. community of scientists interested in a debate around solar-neutrino). Technological megaprojects are of the most interest to analysts, as well as to wider audience. Risks involved in complex technical systems, as well as the social and political consequences of potential use of such technologies, determine the attention to such investigations (e.g., the social studies of military technology or studies of technological disasters). These studies besides questions about physical properties, design, feasibility and reliability of technology help to understand the relationship between political interests and technical judgements.

One of the well-known examples helping to illustrate the construction of credibility is a study by Donald MacKenzie namely *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (1990). The aim of this paper is to understand historical and social dimensions of nuclear missile guidance and its importance to nuclear doctrine in the context of antagonism during the cold war era is the focus of attention (MacKenzie, 1990). MacKenzie suggests that technology under investigation is inseparable from organisation and nuclear strategy in general, and that technological change implies economic, political, cultural and organisational changes, including the conditions of the use of technology and political context (i.e. a missile race with Soviet Union) (ibid.).

In this empirical study MacKenzie focuses on construction of technical facts uncovering the parameters, the pressures and the politics that make up the complex social construction of an equally complex technology and showing how such hard facts as missile accuracy can be disputed. This investigation reveals that missile accuracy is not a natural or inevitable consequence of technical change. It appears to be both technically and socially constructed being a product of conflict and interactions between different social actors – technological, military and political. Accuracy transformed strategic missile doctrine: ‘counterforce’ targeting which meant aiming at Soviet military targets rather than cities made maximum accuracy (rather than reliability or economy) a priority for missile guidance systems. MacKenzie suggests that ‘the invention of accuracy has fuelled, and has itself been fuelled by, the cold war. It has been a shaping force, but has itself been shaped’ (ibid., p.3).

Grasping the role of the social in technical change, he also shows how different societies develop the same technology, comparing US and Soviet paths to increase accuracy of missiles: while US missiles were dependent upon on-board computers for in-flight corrections, Soviet missiles relied on prelaunch calculations of possible errors (reliance on hardware solutions rather than complex software).

The idea of ‘certainty trough’ suggested by MacKenzie echoes similar idea in sociology of science about varying certainty that depends on proximity to scientific (experimental) work – uncertainty about technology is lowest for users rather than producers of knowledge or those alienated from institution/committed to different technology. It is suggested that this certainty trough 'might describe the distribution of certainty about any established technology' (ibid., p.371). The theme of nuclear technology has been elaborated further in STS literature, including nuclear power.

Continuing the theme of credibility of nuclear weapon technologies it is necessary to mention a recent study of credibility in large complex systems based on the concept of sociotechnical repair by Sims and Henke (2012) *Repairing credibility: Repositioning nuclear weapons knowledge after the Cold War*. In this paper the authors explore how scientists maintain their confidence in nuclear weapon performance after the Cold War and how they establish credibility of their work for military and the US government without dramatic demonstration that could be provided by testing. The focus is on how systems are maintained over time in face of systemic crises and change, and how credibility is established and repaired 'through diverse interactions among social, material, and discursive resources' between scientific community and realm of public discourse (ibid., p.329). Sims and Henke discuss the concept of repair which encompasses different practices, such as discursive repair (the attempts to maintain the cultural frames used to describe the world), material repair (the fixing of things that are broken or worn out) and institutional repair (i.e. repair of social structures and practices). Discussing changes and dynamic relationship between material, institutional and discursive elements of repair, they point to the sociotechnical nature of both repair and credibility and the complex relationship between knowledge, credibility and institutional change, where 'weapons knowledge has been continually reinvented and repositioned within new contexts of credibility' (ibid., p.343).

A publicly acclaimed example of a big technological project and its epic failure is a study by Diane Vaughan *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA* (1996). The author discusses credibility of decision-making process in regard to technology deliberating on a theory of normalisation of deviance in organisations where production pressure gets institutionalised, going deep into the structural and sociological causes of the failure of the Space Shuttle Challenger launch in 1986. Vaughan uncovers an incremental descent into poor judgment, supported by a culture of high-risk technology. She explains how conformity to the rules and work culture led to the disaster by revealing how and why NASA insiders, when repeatedly faced with evidence that something was wrong, normalised the deviance so that it became acceptable to them.

This work raises some important issues about the social construction of risk, where culture becomes supreme element in shaping the risk assessment in workplace. Vaughan emphasises on the long-term impact of institutionalisation of the political pressure and economic factors that results in a culture of production. Due to economic constrains, success of the programme was heavily dependent on success of its business model, which was based on maintaining high frequency of launch to meet financial goals. As a result, it was a norm to fly in NASA culture with a known residual risk (so-called 'acceptable risk'). It is suggested that the normalisation of deviance in this case was the outcome of the social forces shaping the culture of the workgroup, the culture of production and the structural secrecy.

Credibility of energy systems also has become a subject of analysis, for example, nuclear power. It is brought into focus and often considered as part of a discussion about future of the world's energy supply with a public relations and marketing campaign launched in various countries deliberating 'clean, environmentally sound energy' (Schmid, 2006). As nuclear technologies are associated with potential risks, the problem of safety, feasibility and reliability of these technologies is seen as core component of constructing credibility of nuclear power.

For instance, a study by Schmid on the history of nuclear reactor design in the Soviet Union provides an insight into complex decision-making processes at the interface between science, technology and the state (Schmid, 2005). She investigates the interweaving of technology and governance and explores the cultural role ascribed to nuclear power in the Soviet vision of social progress and how this shaped professional identities and concepts of risk in the Soviet nuclear power industry. One of the most important aspects of this study is to investigate how safety of this technology is socially negotiated. It is suggested that accepting a reactor as a safe (or not) depends not only on its purely technical features, but also on how it is situated economically, socially and politically, and in particular, how technological artefacts are deployed as 'rhetorical resources to challenge or sustain political and social order' (ibid.).

In another study of nuclear industry Schmid provides a short historical analysis of nuclear power pointing to the differences between past and current proposals for developing civilian nuclear industry in US and Soviet Union/Russia (Schmid, 2006). As such, Schmid considers the question of design of nuclear reactors and changes in approaches to design: the US is 'considering a closed fuel cycle, and idea that had been dismissed previously as not economical', although in Soviet Union this idea was advocated from the outset. The idea of proliferation-resistant design promoted by Soviet Union informed cooperation with other countries for establishing 'credible international fuel supply regimes' (ibid.).

Schmid notices that in these days technical feasibility and economic profitability of these technologies are taken for granted, whereas concerns about safety and non-proliferation have gained significance. Thus, the approaches to credible design solutions of nuclear reactors are in focus. Schmid suggests that the attempts to 'commercialize' nuclear power lead to a shift from legal 'fixes' (i.e. by means of international agreements) to technical 'fixes', which means modified technical design of nuclear reactors promoted by the nuclear industry as 'inherently safe' with 'sensitive technical processes' put in black boxes to prevent proliferation (ibid.). At the same time, the public concerns regarding radioactive waste, as well as public opposition to nuclear power, are encountered with technological optimism or left out of picture. Further commercialisation is presented as a way to normalisation of nuclear energy, but according to Schmid, a reflection on past successes and/or failures seems to be largely missing from current discussions (ibid.). However, such studies help us to understand better socio-technical relations emerging in particular historical context.

The analysis of the STS literature suggests that the questions of credibility, design and expertise are closely interwoven, and credibility-economy of technology often constructed as depending on design and practices that stand behind, as well as expert knowledge of those involved in its creation and use. As such, expertise and design become crucial elements of constructing credibility of technology. In the next sections I will pay more attention to these key themes in STS.

2.3.3. Understanding design practices

As I have shown in the previous sections, from the point of view of politics of technology design and credibility are closely interconnected, even if that can be disputed from the perspective arguing that the properties of technologies are enacted through their use. Constructive nature of design is always emphasised in STS analysis, where various aspects of design are problemitised, e.g. expertise, strategy, participation, public debate, consequences, politicisation, etc. Recognising the diversity of thinking in the field, in this section I will pay attention to the main approaches and concepts and consider a few studies which are specifically focused on design practices and design of particular technological artefacts.

Generally, design can be defined as a 'set of interconnected and heterogeneous practices aimed at bringing a new artefact into being' (Storni, 2010, p.2). In STS design is understood as a complex process of articulations and (de)stabilisations of artefacts with an emphasis on heterogeneous and situated nature of design practices which are widely engaged with technical, social and political complexities. It is widely accepted that questions about design are not only technical but also social, and include definition and distribution of roles between the object and its environment (Callon, 1991). ANT is often employed by STS scholars for studying design practices as it offers a symmetrical approach based on hybridisation of the social and the technical (Storni, 2010; Latour, 1991; Law, 1992b; Callon, 1986).

According to Woodhouse and Patton, design can be seen as involving both professional designers ('proximate designers') and so-called 'design by society' (Woodhouse and Patton, 2004, p.1). Design by society means that social norms and values are reproduced in products of design; innumerable persons, institutions and organisations can participate in design process with varying degree of immediacy (ibid.). It is characterised as 'somnambulism' or 'sleepwalking' as often innovation moves along the paths 'not deliberately chosen by socially sanctioned processes' producing unintended consequences (ibid., 2004, p.6). Design by society can be viewed as a conceptual approach to explore ‘the larger universe of social institutions and processes that shape the artifacts, symbols, and systems of contemporary life’ (ibid., p.4). The social construction of technology, called by Grint and Woolgar (1997) a ‘design-centred perspective’, probably, represents it in the best way providing investigations of how artefacts and sociotechnical systems are shaped by social groups and other social factors (e.g. evolution of a bicycle).

Proximate design involves professional designers and signifies careful process of deliberation and negotiation, although proximate designers are not free from constraints and uncertainties established through complex social arrangements (Woodhouse and Patton, 2004). The studies of proximate designers and their practices address on different areas, e.g. engineering, architecture, product design, etc. The investigations into design practices often focus on processes and transformations behind design of particular technological artefacts. Engineering practices, which are closer to those traditionally addressed by STS, are of a particular interest for this thesis. They are instantiation of a careful process of negotiation and balancing between attempts to control design process and the messiness of everyday material practices. In the studies of engineering and design practices particular attention is paid to stabilisation of technological artefacts and how initially contingent character of artefacts becomes progressively less ambiguous and more fixed, with capacities and effects embedded in material form (Grint and Woolgar, 1997; Storni, 2010).

Often these studies are based on ethnographic observations of the world of engineers. For instance, Louis Bucciarelli in the work *Designing Engineers* describes evolution of three projects exploring how the form and function of products of engineering design are determined and what inner dynamics of technological choice are (Bucciarelli, 1994). Main assumptions are based on understanding engineering design as a social process that involves constant negotiation between various actors. Bucciarelli shows the differences between the ideal image of design as an instrumental process and the reality of design as a historically situated social process that is full of uncertainty and ambiguity. Another example is a series of ethnographic studies of engineering practices conducted at different sites where various ‘effective practices’ were observed, *Everyday Engineering: An Ethnography of Design and Innovation* edited by Dominique Vinck (2003). This volume provides a deeper inside into the sociotechnical world of engineering paying attention to design, change management and innovation. In three parts it introduces the complexity of technical practices, examines the social and cultural environment of engineers, technical action practices and motivations, the role of writing practices and graphic representations that are decisive in the achievement of technical performance. Vinck (2003) points to the socio-technical complexities of technical practices in which an object can be viewed as a node in a network and analysed from different perspectives.

Some studies about design of technologies reproduce stories of design as histories based on the analysis of documents and retrospective interviews. One of such studies is the one by John Law *The Olympus 320 Engine: A Case Study in Design, Development, and Organizational Control* (1992b). In this study Law discusses a story of the design and development of the engine that was supposed to power Concorde airplane, examining problems that this project experienced, its failure and the organisational consequences of this failure. With the focus on the organisation of design, on methods of modelling, and on the process of testing, the author is interested in the way in which organisations seek to control their environments. Law suggests treating design and development as ‘a set of strategies for control’ (ibid., p.410). One of the key assumptions made here is that the process of design can be viewed as a strategy for controlling the aspects of *physical* environment and as a method for trying to control the *social* environment (ibid., p.411).

Law also introduces a notion of a ‘negotiation space’ as a private area, physical and metaphorical, that is not accessible for outsiders, and where plans and ideas can be generated, explored and tested invisibly to those on the outside (ibid., p.412). A negotiation space can be seen as a boundary between inside and outside, physical, organisational or legal. In the case discussed by Law it was a contract that helped to reproduce a set of legal, organisational and spatial methods to draw this boundary, defining who would and who would not contribute to the design of the engine. The contract was also a procedure to model the social world and to predict the character of social and technical relations. But political relations could not be modelled, although a general model of the political process acted as a 'kind of backdrop' to contractual arrangements (ibid., p.437). The change of the political context (i.e. the change of the government in the UK) was recognised as a threat and eventually was crucial for the project's destiny, as the aircraft and its engine were cancelled by the new government despite of the successful test flight.

Law talks about both technical and social modelling and heterogeneous engineering[8]. His concern is that in technological talk the social is often marginalised as an 'intractable nuisance' and 'escapes the technocratic dream of complete prediction and control' (ibid., p.440). Law concludes by suggesting that it is often the people, the organisations or the politics that are said to fail, rather than the technology itself.

Another interesting study about heterogeneity of design practices is offered by Cristiano Storni *Unpacking Design Practices: The Notion of Thing in the Making of Artifacts* (2010) where he suggests to direct attention to how elements of different nature relate, change and move on together in design practices. Based on a detailed case study of design and production process of a mundane piece of technology – a silver ring, Storni observes a movement from vague, multiply issued object to a black boxed, clearly defined and concrete artefact (Storni, 2010). Emphasising relational, material-semiotic aspects of design Storni attempts to offer a perspective that might help to account for the complexity and heterogeneity of design practices with conflicting opposite tendencies and with a focus on movements and transformations that lie behind artefacts. For Storni design is not only plan, intention, prevision, and reification but also emergence, detour, creativity, improvisation, surprise and novelty. In this process disorder, confusion, failure, and detour perform as constructive moments too (ibid.). Design can be viewed as process of progressive closer, material construction, stabilisation and organisation of heterogeneous resources that form a network of associated human and nonhuman (material and technological) actors which enact different divisions of the world (ibid.). Expert skills and knowledge, established practices and organisations are seen as outcomes of the

[8] I will discuss heterogeneous engineering in more detail in the section 'Actor-network theory as a theoretical resource'.

design and production process rather than preconditions and causes of it. The next section will discuss this aspect of technology construction in detail.

2.3.4. Experts and expert knowledge

Controversial technological projects are ideal sites for studying the production of scientific knowledge and negotiation of expertise and expert status, as in the case study analysed in this thesis. This makes the problem of credibility of expert (including scientific) advice and credible expertise, which is recognised and disputed in STS literature, extremely important. The concern of this part of literature review is with professional expertise and related issues where perspectives to study expertise and professional expert communities are discussed.

The problem of expertise is intrinsic part of discussions of credibility, or credibility-economy as in Shapin (1995). It is suggested that in the world characterised by familiarity people tend to take each other's claims at face value to maintain their cohesiveness, and 'it is distrust, scepticism, and the demand for explicit warrants for belief that need specially to be justified and accounted for' (Shapin, 1995, pp.269-270). Formal warrants are needed in the situation of the economy-credibility obtaining between expert groups and laity, such as institutional affiliation, expert consensus, the observance of methodological procedures (ibid.). The economy of credibility obtaining between expert groups in modern differentiated societies 'lacks the resources of familiarity, while it possesses an array of inducements to distrust and skepticism' (ibid., p.270).

One of the most prominent studies on scientific and expert advice is the one by Stephen Hilgartner (2000) *Science on Stage: Expert Advice as Public Drama*. The public face and authority of science, which can be problematic, and in particular, how advisory bodies achieve and defend their credibility, is the key question discussed in this book. The analysis casts light on persuasive rhetoric, stagecraft, information control and identity of advisory bodies. Using a metaphor of performance Hilgartner examines struggles over the credibility of scientific advice (how it is produced, contested and sustained) and how advisory bodies work to bring authoritative advice to the public stage. He suggests that advisory bodies selectively reveal and conceal themselves, actively presenting some things to their audiences while hiding others 'backstage'. The book demonstrates that techniques for information control (e.g. 'stage management', strategic self-presentation) play a fundamental role in efforts to create and contest expert authority. The author compares the production and presentation of National Academy of Sciences reports on diet and nutrition, one successful and authoritative, the other widely challenged, arguing that the crucial factor for construction of credibility is the ability to present a coherent and unified 'front' to the scientific community and the public. Breaks of the stage management can compromise the scientists' authority. Hilgartner shows that the social dimensions of scientific texts (e.g. advisory reports) are crucial for controlling the disclosure of information and for structuring relations between experts and their audiences. Creation of authoritative reports depends on the system of 'stage management' which implies separation between front and backstage to conceal deliberations that might undermine the appearance of unity. Discussing boundaries between political and technical, Hilgartner points to the use of expert advice as indispensable resource by governments for formulating and justifying policy. Removing some issues from the political domain by transforming them into technical questions changes the perception of their character and consequently affects judgements about who should resolve them. As such, 'a veneer of scientific rationality masks the political nature of important societal decisions' (ibid., p.4).

Some generalisations and universal points in regard to experts, their status, expert knowledge and disagreements are made in several studies about expertise and expert communities acting in various professional fields (Martin and Bammer, 1996; Martin, 1991; Martin, 1996; Martin, 2008-2009; Rifkin and Martin, 1997; Martin, 1982, Martin, 1983).

Although science is sold to the public as objective knowledge that is untainted by social factors, it is argued that scientists who perform as experts are always influenced by their context, and in particular, by the ideas of dominant groups in the society, professional hierarchies, bureaucratic structures, and concerns about status, prestige, availability of resources, etc. (Martin, 1991). Besides, it is argued that experts are often tied to powerful interest groups or power structures, such as governments or industry bodies, who are seldom challenged in fundamental ways (Martin, 1996). In these situations it is possible that expertise might be used ‘to serve the institution at the expense of the public interest’ (ibid., p.4).

The problem of achieving scientific consensus in situations when various expert opinions exist is also investigated. It is suggested that the complexity of the problem, which might have a number of possible explanations and solutions, and social interests involved can lead to disagreement between experts, as in the case of chronic musculoskeletal problems where expert opinions differed in explanation (Martin and Bammer, 1996). Often methods used to investigate a phenomenon or the way findings are interpreted can be criticised from other perspectives (ibid.). Martin and Bammer explore the incentives to pursue certain types of explanations that different groups of experts have, and come to the conclusion that ‘proponents of different explanations sincerely believe their stands’ (ibid.). It can happen, in authors’ view, because different groups of professionals have different experience and knowledge (e.g. a psychiatrist may know a lot about psychosomatic disorders). Once a specialist adopts one of the explanations, he/she will be looking for the evidence to support it and to find holes in other explanations, and ‘no malice or dishonesty needs to be involved’ (ibid.). This can apply to proponents of any explanation, especially when there is enough ambiguity, as well as power and resources to encourage advocacy or particular explanations. It is argued that there is no way to be objective ‘in reality’ as in controversial situations ‘there is no universal standard, no ultimate facts, to which to appeal’, and the beliefs and commitments are influenced by social factors and personal circumstances (ibid.). The authors’ main idea is about the importance of potential ‘vested interests’ that must be taken into account when assessing evidence and expert arguments.

Martin argues that the attribution of expertise to someone depends on social processes of persuasion and contestation and does not automatically flow from their knowledge (Martin, 1991). Developing the theme about the social processes by which expert status is negotiated and constructed, Rifkin and Martin refer to the concept of boundary work to understand techniques and activities used by expert groups to separate themselves from others (Rifkin and Martin, 1997)[9]. These techniques include credentials, jargon, rhetorical strategies, control over journals and training of new recruits etc. Rifkin and Martin define expert status which depends on a measure of authority as ‘being in the eye of the be-holder’ emphasising its negotiated character, which means that such status is provisional and potentially changeable, resulting from confrontation, implicit agreements and other processes of face-to-face interactions (ibid.). The analysis of expert ‘performance’ in technical conversations suggests that expert-client relationship can be seen as a relationship of influence, where the relational part of communication in, for example, technical decision-making is important to much greater extent than usually imagined (ibid.). The credibility of experts also depends on their personal credibility as individuals (Martin, 1991, p.32).

Expert establishment and their credibility is often criticised in literature. The idea of expert status as a social construct helps to explain practical aspects of challenging and discrediting experts and expertise. Some social scientists see expertise as overrated in modern society where knowledge is perceived as a crucial commodity, and it is experts themselves who have a vested interest in expertise becoming a basis for status, power and wealth (Martin, 1991). Martine describes the way how to tackle the experts and ‘strip’ them bare by becoming an ‘expert in weaknesses of the orthodox view and in ways to exploit those weaknesses’ (ibid., p.10). He points to a variety of ways how to counter facts presented by experts and challenge underlying assumptions, including those made in mathematical models: challenge facts directly, point out counterexamples and uncertainties, expose assumptions hidden behind the facts and conclusions, deny implications of assumptions, etc. The ways to discredit experts themselves are also suggested, e.g. expose their mistakes, inconsistencies, vested interests, and attack the relevance of credentials (ibid.).

Taking this line of argument further, the study by Michael Lynch and Simon Cole (2005) *Science and Technology Studies on Trial: Dilemmas of Expertise* discusses

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[9] In my study I also use the concept of boundary work and boundary organisations in regard to expert communities around Wave Hub. I will discuss it in detail in Chapter 7 ‘The politics of expertise: Wave Hub as a focus and source of expert knowledge’.

the problem of credibility of STS expertise and the questions about STS own expertise. This paper exemplifies STS engagement in a public controversy about 'a contested form of 'scientific' knowledge'. Lynch and Cole discuss materials from the legal case in which one of them (Cole) agreed to perform as an expert witness, and his own expertise was subjected to an admissibility hearing. The authors present the materials organised around a series of dilemmas which helps to summarise the difficulties that STS scholars (and other social scientists) might face when presenting their research in public arenas (when they attempt to engage the 'public sphere') due to 'second-order status' of social science concepts and findings (ibid., p.295). Discussing a number of dilemmas (demarcation between science and non-science, the constitution of one's own 'relevant scientific community', comparison of 'scientists' with 'historians' or 'scholars', how to acknowledge epistemic limits without appearing to confess to procedural errors, and how to describe a constructionist analysis without seeming to evince general distrust or scepticism), the authors suggest that the 'constructionist orientation' is not widely accepted in the so-called 'public sphere', e.g. science press, the courts, etc., where STS field is examined through the prism of a 'more dichotomous classification of expertise': 'sound' or 'junk', 'good' or 'bad' science; 'generally accepted' or not 'generally accepted' knowledge (ibid., p.296). This 'boundary work' can be improved with the help of STS scholars, but to do that the question of what STS own expertise involves needs to be seriously comprehended. They refer to the work by Collins and Evans (2002)[10] who offer a classification of expertise which would be suitable in case of public science controversies. Criticising this provisional framework for assessing expertise as being non-satisfactory, Lynch and Cole see it as a start for thinking about STS own expertise. Opposing to the notion of a 'generalist' STS expert with no specific knowledge about the subject under scrutiny, they argue that individual 'expertise' (e.g. 'Cole's immersion in the subject matter of fingerprint identification') creates the ground for making an authoritative opinion and improving his argumentation with time (ibid., p.297). In conclusion, the authors suggest that credibility for the field

[10] A prominent debate in Social Studies of Science 'The Third Wave of Science Studies – Studies of Expertise and Experience' includes papers by Collins and Evans (2002, 2003), Jasanoff (2003), Brian (2003), Rip (2003). I do not perceive it as my task to analyse this debate in detail. However, references to papers will appear to various parts of the thesis.

'would arise less from any abstract theoretical apparatus and more from the contingent set of associations, press clippings, and precedents that accrue as the field becomes entrenched and normalized' (ibid., p.297).

Overall, a critical review of existing literature in STS shows that the analysis of social processes that shape technological systems and artefacts has been the focus of attention for a few decades. The variety of theoretical perspectives such as the social construction of technology, the concept of technological systems, the network approach were put forward by such scholars as Michel Callon, John Law, Trevor Pinch and Wiebe Bijker etc. for analysis of technological development, 'content' of technologies and their environment. Studies on the politics of technology, policy and political character of technology are an essential theme for ongoing discussion in STS (Hilgartner, Winner, 1980, Grint & Woolgar 1997, Joerges 1999, Webster 2007). Innovation policy and the underlying concepts and rhetoric accompanying it, also seem to be an 'ample ground' for STS analysis (e.g. Nowotny, 2007). The issues associated with renewable energy are very diverse, taking in innovation and development of new technologies, the financial and political mechanisms to stimulate the growth of the sector, the perception of renewable energy by public and its potential to reduce CO_2 emissions, its role in providing energy security and diversification of energy sources. However, the studies of policy and politics of technology in STS have not looked at issues in the field of renewable energy so far. And only a limited number of studies on renewable energy in STS can be detected, and most of them are inspired by actor-network theory.

2.4. Actor-network theory as a theoretical resource

In this section I aim to provide a general overview of actor-network theory (ANT) and its main principles and concepts that help me to build a theoretical framework for my analysis[11]. ANT is also employed as a methodological strategy in this thesis.[12]

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[11] The analysis in two empirical chapters is mainly informed by ANT: Chapter 4 Emergence of a macro-actor: a possible history of Wave Hub and Chapter 5 Policy as an actant: from scale to agency.

ANT is distinguished from other sociotechnical approaches: it suggests employing the same analytical and descriptive framework dealing with both human and nonhuman actors which form a network and wherein their identities are defined through their interactions with other actors. As such, it refuses to reduce explanation to natural, social or discursive categories while recognising the significance of each. Technology cannot be perceived as an autonomous thing – it contains a variety of political, social and economic elements as well as science, engineering, and the particular histories of these practices (Cressman, 2009). ANT can be employed for analysis of a technological project and its environment. The idea of heterogeneous nature of actor-networks helps to link technical and non-technical, human and nonhuman elements which are equally important for the construction of a sociotechnical network. The concept of translation, used to describe processes through which actors relate to one another, can help to conceptualised what is actually occurring during the process of innovation and to bridge the gap between various aspects embedded and combined in technology, which in turn can be seen as an actor-network (or a macro-actor). ANT approach to the ideas of scale, micro/macro distinction and context/content dichotomy also makes it a suitable strategy for studying technology development, success or failure of technological innovation, and its trajectory.

2.4.1. Actors, networks and process of translation

The origin of the ANT approach can be found in the need for a social theory to be adjusted to science and technology studies. The founders of ANT – Michel Callon, Bruno Latour and John Law – developed this distinctive approach to social theory and research which is characterised by its material-semiotic nature. One of the most discussed papers is Michel Callon's 1986 publication explaining the basic notions and introducing the main concepts informing ANT as a new approach to the study of power (or sociology of translation). Callon (1986) describes the story around the population of scallops in St. Brieuc Bay and the attempts of scientists to develop a

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[12] Methodological reflections of ANT are discussed in Chapter 3 Methodology.

conservation strategy for that population (studying the role played by science and technology in structuring power relationships). The study was based on three principles – generalised agnosticism (impartiality between actors engaged in controversy), generalised symmetry (the commitment to explain conflicting viewpoints in the same terms) and free association (the abandonment of all a priori distinctions between the natural and the social).

The idea of heterogeneous network (or socio-technical network – Callon, 1991) is at the heart of actor-network theory. According to ANT, human and non-human actors are linked together in a web of relationships referred to as an actor-network. A network seems to be a neutral term for interconnectedness of points or nodes of any material and form, an 'apt image for describing the way one can link or enumerate disparate entities without making assumptions about level or hierarchy' (Strathern, 1996, p.522). The metaphor of heterogeneous networks suggests that 'society, organisations, agents, machines are all effects generated in patterned networks of diverse materials' (Law, 1992a, p.380). In other words, all phenomena are the effect or the product of heterogeneous networks (networks of heterogeneous relations). When a network operates so smoothly that the connections and the separate identities are no longer discernible, we can then speak of an actor-network, a network that (successfully) pretends to be one actor (Porsander, 2005). As Law explains the term: 'actor-network – an actor is also, always, a network' (Law, 1992a, p.384). Theoretically, networks are without limit; one can always discover networks within networks (Strathern, 1996, p.523).

To understand the mechanism of ANT it is necessary to clarify the notion of punctualisation which can be seen as a precarious simplificatory effect accomplishes the idea of abstraction. It is assumed that all phenomena are the effect or the product of heterogeneous networks. While a network act as a single block, it is replaced by action itself and we deal with a single actor; network as it is disappears (Law, 1992a). Thus punctualisation effect is seen as an important feature of the networks. John Law (1992a) suggests that punctualisation is a process or an effect, rather something that can be achieved once and for all. It goes in line with his statement that 'social structure is not a noun but a verb' (ibid.). Similar idea with an emphasis on process is expressed by Latour: 'one should be speaking of actor-networking rather than actor-networks' (Gherardi and Nicolini, 2005, p.287).

According to Callon, an actor-network is a result of a transformation that can be best characterised as a process of translation. Concept of translation is central to ANT. In general, translation can be viewed as a way of describing movements of different forms – of knowledge and cultural practices, but also of technology and artefacts (Czarnniawska and Hernes, 2005), a concept to describe processes through which actors relate to one another (Gad and Jensen, 2010). John Law defines translation as a verb which 'implies transformation and the possibility of equivalence, the possibility that one thing (for example an actor) may stand for another (for instance a network)' (Law, 1992a). Translation can be understood as a process of negotiation by means of which certain actors assume the authority to act and speak on behalf of others. Via translation, actors deliberately attempt to influence others to accept renditions of problem definitions and potential solutions as valid and legitimate (Holmström and Robey, 2005).

Callon (1986) defines four moments of translation: problematisation (includes the interdefinition of actors, e.g. the fishermen, scientists and the scallops of St. Brieuc, and the definition of obligatory passage point); interessement; enrolment; mobilisation.

Problematisation is an incipient stage of building a network. At this stage an initial set of actors defines a problem and initiators attempt to impose their suggested solution on other actors. Their goal is to establish themselves as an obligatory passage point and become indispensable in the process. Interessement is a series of processes by which initiators attempt to enrol other actors who are becoming locked into roles that had been proposed to them. Enrollment is performed by the means of strategies used to define and interrelate the various roles initiators allocated to others; the entities in emerging network become coordinated and aligned. Motivation is central to enrolment and at this stage the actor-network achieves stability. The network starts to speak as one, it has a sole and ultimate spokesman, starts to operate as a recognisable actor – a unit, and produce some effect through its intermediaries (Callon, 1986). An intermediary for Callon is 'anything passing between actors which defines the relationship between them' (Callon, 1991, p.134). Intermediaries describe and compose their networks, they 'order and form the medium of the networks they describe' (ibid., p.135).

In his later work Callon (1991) talks of four main types of intermediary: texts, or literary inscriptions, such as books, reports, articles etc.; technical artefacts – relatively stable and structured groups of non-human entities which together perform certain tasks; human beings and the skills/knowledge incorporated; money in all its forms, although in practice we usually deal with 'hybrid intermediaries' (ibid., p.138). Intermediaries are the principle forms of the 'links' in a chain or network. Exploring the correlation between two terms, 'actor' and 'intermediary', Callon (1991) claims that they can be seen sometimes as synonymous. For Callon, whether we view an agent as an actor or intermediary entirely depends on perspective (Newton, 1996). Actor, in Callon's view, is any entity able to associate texts, humans, non-humans and money and to define and build a world filled by other entities with histories, identities, and interrelationships of their own. Actor can be a principle author of actions in a network. As Callon (1991) stated, 'actor is an intermediary that put other intermediaries into circulation – that an actor is an author'. In other words, all actors might be viewed as intermediaries, links in a chain which both connect and define the relationship between the agents concerned, and sometimes they can be treated as actors, as the principle authors of particular effects (Callon, 1991; Newton, 1996).

The distinction between mediators and intermediaries is also a key question. Latour (2005) considers the correlation between mediators and intermediaries suggesting that an intermediary is what transports meaning or force without transformation when a mediator transforms, translates, and modifies the meaning or the elements it is supposed to carry. Mediators might count for one, for nothing, for several, or for infinity, and their input is never a good predictor of their output. On the other hand, intermediaries are taken as a black box, for practical purposes, counting for one, even if it is internally made of many parts. Latour (2005) uses an example of properly functioning computer as a complicated intermediary and a banal conversation as something that may become a very complex chain of mediators; but if computer breaks down it may turn into a complex mediator, while a conference panel may become an uneventful intermediary due to its predictability in decision-making.

Inscription is another important concept that needs to be mentioned. Lanzara & Morner (2005) define inscription using Latour's approach as 'the act (or sequence of acts) by which humans cast relevant components of their agency and knowledge into artifacts to which action programs and capabilities are *delegated'* (p.72). As a result of delegation, artefacts become holders and dynamic vehicles of human agency, performing functions in complex networks of human and non-human agents. In other words, through inscription actors embed their social agenda into technical artefacts what makes technical objects to be treated as a programme of action that coordinates a network of social roles (Holmström and Robey, 2005).

The apparent complexity of ANT leads to some criticism for insisting on agency of nonhumans, descriptive nature and lack of explanations for social processes. The controversy around ANT and its naming led to revision of the concept. Obviously, 'actor-network' is a name, a term which embodies a tension – a tension which lies between the centred 'actor' on the one hand and the decentred 'network' on the other (Law, 1999). This has led to scrutiny and revision of the term 'actor-network theory'. As Czarnniawska and Hernes (2005) noted, actor-network theory had been variously interpreted as "actors and their networks", "actor's network", and even as whatever approach used by authors writing a text. Bruno Latour, one of the founders of ANT, tried to recall the theory by saying that '...there are four things that do not work with actor-network theory; the word actor, the word network, the word theory and the hyphen! Four nails in the coffin.' (Latour, 1999, p.15) Although in his later work *'Reassembling the Social: An Introduction to Actor-Network-Theory'* (2005) Latour reversed his statement and defended all the elements of the approach's name '...including the hyphen!' (Latour, 2005, p.9). However, in his comments Latour still calls the label 'actor-network theory' awkward and confusing suggesting that the word 'sociology' would work best using the notion 'sociology of associations' (ibid.).

Law (1999) explores the tension central to the notion of an 'actor – network' which is 'an intentionally oxymoronic term that combines – and elides the distinction between – structure and agency' (Law, 1999, p.1). It is proposed that actor-network theory may be understood as 'a semiotics of materiality'. According to Law, 'it takes the semiotic insight, that of the relationality of entities, the notion that they are produced in relations, and applies this ruthlessly to all materials...' (ibid., p.4). Considering the complexity of ANT, Law (1999) calls the theory ‘diasporic’ pointing to the fact that it has converted itself into a range of different practices which have also absorbed and reflected other points of origin: from cultural studies; social geography; organisational analysis; feminist STS. He states that its parts are different from one another but they are also partially connected, and it is not simply a random set of bits and pieces, ‘wreckage spread along the hard shoulder of the superhighway of theory’ (ibid., p.10). Finally, he uses the metaphor of the ‘*fractal’* to explain the dualism of simplicity and complexity – ‘more than one and less than many’ (ibid., p.12).

As Czarnniawska and Hernes (2005) point out, the most provocative aspect of ANT is its symmetric treatment of humans and non-humans and its focus on artefacts, which led to certain controversy around it, although it was clarified by Law that this symmetry is an analytical stance, not an ethical position in ANT (Law, 1992a).

Criticism is also expressed by authors who apply actor-network theory in their research, but adopt a selective and utilitarian application of ANT. A critical perspective on symmetry was expressed by Newton (1996) in his work on discourse and agency in an analysis of the recruiting process in a life insurance company. Examining translation and convergence processes within the network, he argues that it is difficult to maintain an even symmetry between human and non-human actors, just as it is also difficult to maintain a symmetry between human actors, thus a consideration of inequality might be re-inserted into actor-network theory. The main argument here is that there is little analysis of the effects of location in a network, or access to particular locations, although the location of the actors appeared critical to their ability to effect translation down the networks, particularly their location within the organisational hierarchy. Consequently, there is an asymmetry in the performance of these human actors (Newton, 1996).

Nevertheless, inclusiveness of non-humans in the list of actors, despite some criticism, is an important feature of this approach. It 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 which is of particular use in studying contemporary organisational form (Lee and Hassard, 1999). Thereby, the application of ANT approach often leads to anthropomorphisation of objects and construction of macro-actors.

2.4.2. The concept of macro-actor

Macro-actors are actor-networks that coalesce in such a way that the whole is seen as having projects (Feldman and Pentland, 2005). Organisations, institutions, markets, technologies, etc. can be perceived and analysed as macro-actors.

The illustrative example of construction of a macro-actor is a case of Renault *vs.* Electricité de France (EDF) used by Callon and Latour, where they show how macro-actors emerge and how through the process of translation they assume the authority to speak and act on behalf of the networks which are comprised of mobilised and enrolled micro actors, humans and non-humans (Callon and Latour, 1981). It is shown how one actor can be able to stabilise power relations through 'associating the largest number of irreversibly linked elements' (ibid., p.293). The approach to seeing a corporation as a macro-actor helps to understand what strategies and corporate bodies are made of (Hernes, 2005).

In another study Latour (1988) tells us about complex networks among science, society and nature, in particular about hygienist movement in 19th century in France and appearance of a macro-actor – Pasteur and Pasteur Institute, which became an indisputable authority of knowledge on issues on microbes and hygiene. Latour explores the process of construction of a stable network through alliances, which resulted in emergence of this institutional macro-actor. He pays special attention to the power relations between multiple actors and shows that a revolutionary scientific discovery is a result of a struggle between competing social forces (Latour, 1988). This case also shows how relations between micro actors are produced and affected by this evolving institutional macro-actor (ibid.).

Other examples of macro-actors abound – it might be a cultural city project (Porsander, 2005) or open-source software project (Lanzara and Morner, 2005), a technological strategy (Tryggestad, 2005), a technology or any artefact, for example, an engine (Lindahl, 2005), it can be a market (Callon, 1999) or even organisational routine which is seen as a quasi-object that can stabilise networks – organisations and organisational fields (Feldman and Pentland, 2005). As a rule, such approach is based on Callon's model which describes the macro-actor associated with a single project and is labelled by Gherardi and Nicoloni (2005) as an 'entrepreneurial' version of ANT.[13] Entrepreneurial (or managerial) tactics of translation is associated with four typical phases mentioned above: problematisation, interessement, enrolment and mobilisation. Based on Callon's methodology, focused around the winning actants, it organises the plot around them considering the emergence of an actor-network as a unique and unrepeatable chain of events, a process that must be investigated according to its historical and contextual circumstances. Actor-networks grow, accumulating resources and comprising human and non-human agents, and at some point they impose themselves as 'macro-actor' (Gherardi and Nicoloni, 2005), for which Callon and Latour (1981) use a comparison with the Leviathan, a 'monster' who is a living thing. This super actor can be viewed as a force which is capable to associate many other forces to act as a single entity, like a 'single man' (ibid., p.299). Other actors whose interests, desires and forces they translate more or less successfully make them grow or shrink (ibid.)

To understand the growth of a macro-actor the concept of 'black boxes' is employed (Callon and Latour, 1981), which is one of the central concepts in the sociology of translation. Callon and Latour together in their work first used this term considering a growth of a macro-actor and micro-macro relations (ibid.). A 'black box' is a metaphor borrowed from cybernetics and originally used 'whenever a piece of machinery or a set of commands is too complex' (Latour, 1987, p.2-3). Thus, a black box is drawn around it, allowing it to function only by giving it "input" and "output"

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[13] Providing examples of using ANT in different research contexts, the authors suggested that another version of actor-network theory named 'ecological' can be used to illustrate the macro-actor around a much wider research field. The main difference between the two versions of ANT is that they are constructed around different conceptions of agency – focused and dispersed. The ecological model favours an approach that privileges the actions over the actors, putting emphasis on the context and negotiated nature of social order, it rests on the intricacies of actors' relationships and pays a greater attention to powerless actors; the rhetoric here is less heroic and more quotidian. Assuming that modern organising is not best captured in a format based on narrative trajectory, it is suggested that both versions of ANT are complementary and taken together show 'the capacity of the translation approach for generating rich, thick and convincing stories' of innovation and organisational change (Gherardi and Nicoloni, 2005, p.306).

data; when a machine runs efficiently or a matter of fact is settled, the inner complexity doesn't have to be known. In his work *'Science in Action'* Latour elaborated the concept of a black box for the sociology of science, labelling scientific theories as black boxes that are used as the bases for other theories (Latour, 1987). Generally, a black box can be interpreted as a combination of ideas, things and people whose output is assumed to be true.

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). It is suggested that an actor grows with the number of relations it can put in black boxes – the more elements it can place in black boxes (objects, forces, modes of thoughts) the broader the construction of a macro-actor (ibid.). It is important to note that these black boxes never remain fully closed or properly fastened '...although a macro-actor can do *as if* they were closed and dark' (ibid., p.285).

It is emphasised that 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). Thus, a macro-actor can be understood as a micro actor 'seated on top of many (leaky) black boxes', being not more complex than micro actors (ibid., p.286). If the process of creating alliances is successful, a macro-actor presents itself as a solid and indivisible entity; the traces of its construction are wiped away (Czarniawska and Hernes, 2005).

The concept of a macro-actor disseminates micro/macro distinction in social theory and helps to understand the approach to the discussion of scale and context/content dichotomy in ANT. It is noted that ANT has elaborated an 'alternative understanding of observable differences in scale' (Helgesson and Kjellberg, 2005, p.145). The main argument here is 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 empirical studies that explicitly refer to the concept of macro-actor are diverse, although not very numerous. Based on empirical evidences, they can serve as explanatory examples, specifying the concept and demonstrating different understanding of its implication for analysis. The most substantial and illustrative collection of essays exploring the emergence of power and macro-actors is the volume edited by B.Czarniawska and T.Hernes *Actor-Network Theory and Organizing*. The attention here is directed to different aspects of ANT and the process of construction of macro-actors. The emphasis on symmetrical treatment of human and non-humans and anthropomorphisation of artefacts and other objects is often in focus.

For example, Porsander (2005) discusses the emergence of an actor-network around the project that aimed to turn Stockholm into the 'cultural capital of Europe 1998'. The software programme (a computerised administrative system for the project named Lifebuoy), which created a face of the project, got a voice and could tell the reader its story of success. The story illustrates the importance of artefacts in organising activities and inspired by work of Bruno Latour and Michel Callon. It shows the construction of a large action net (which performed the 'cultural capital') and the emergence of an actor-network around a small temporary organisation called Stockholm '98. Porsander explores in detail the construction of an actor-network (macro-actor): who were the relevant actants, the obligatory point of passage, how a pact was formed between different actants and how various negotiations were performed, and finally finding the spokesperson. At the end, anthropomorphisation of the macro-actor was manifested in comparison of the emergent actor-network with a human body, which is used by the author to describe the final construct.

Another study, analysing a technological strategy as a macro-actor constructed of diverse materials and humans, discusses a flexible manufacturing system, which aimed at cost reductions in the flow of materials and at cut on operating expenses in general (rationalisation), but was never introduced (Tryggestad, 2005). Although it represented an emerging network supported by the management and system's engineers, the weight of the associations making up the rebel network that opposed the initial proposal appeared to be 'too heavy to counteract' and more strategically important for constructing the new order (ibid., p.43). Discussing the formation of alliances and a war between plans and anti-plans around implementation of a technological strategy, Tryggestad shows how the plan developed in line with the overall strategy of the company aiming at rationalisation ‘became marginalised by an opposing collective’ (ibid., p.43). Using empirical cases, it is also discussed how strategies can transform people into objects and non-humans into actors, and how the effect of ‘humanness’ is coproduced using heterogeneous materials such as machinery or texts.

The networks that assume strategic importance are also in focus in the study that discusses the construction of diesel plants, where one engine was ‘dictating’ the ways of organising and determining the ‘hierarchies of people and objects’ (Lindahl, 2005). Analysing the case of a diesel power plant where the engine had a considerable influence on the whole project, Lindhal points to the constraining effect on action on the site that the engine had, and this effect came from the technology’s physical properties, design and technical function. This study supports the argument about ‘stabilising and sanctioning effect’ that artefacts might have on the relations within a network, their regulating effect on action and processes within large systems. In other words, the technology can exhibit ‘a strong “managing” quality’ (ibid., p.51) for the network of relations formed around it.

Stepping beyond humans and artefacts, Feldman and Pentland (2005) consider organisational routine as a ‘quasi-object’ which is able to stabilise other networks such as organisations and even organisation fields, and how organisational routines contribute to the creation of macro-actors, including themselves. They suggest that ANT perspective can provide an insight into the construction of organisational routines as macro-actors and their power offering a new conceptualisation of routines as networks of associations, or as ‘networks of actants that we create into a thing by narrating them’ (Feldman and Pentland, 2005, p.109). For Feldman and Pentland organisational routines have potential not only to become macro-actors, but also to play a role of actants in constructing other macro-actors (larger networks, i.e. organisations or whole field of organisations). The importance of organisational routines is emphasised – ‘they operate as actants for participants in many diverse organizations and help shape the legitimacy and structure of an open-ended set of other macro-actors’ (ibid., p.106).

In another study in the same volume Hernes (2005) discusses a university routine and the battle between institutes over a recruitment case, suggesting viewing organisations as nexus in which institutional macro-actors operate using other actors as intermediaries. Institutional macro-actors play an important role in decision processes and influence decision-making (which can be seen as 'micro actors' battles'), although often this influence is not visible (Hernes, 2005, p.128). In organisational decision-making processes individuals represent various institutional macro-actors, and through the enactment of these individuals the institutions come to life. Due to the specificity of structured decision-making processes, the individuals perform as actors competing for influence, and their influence depends in part on the institutional legitimacy they are associated with; they exercise power by virtue of which macro-actors they speak on behalf of. Analysing organisational decision making processes, Hernes argues that the order of the entry of institutional macro-actors had an impact on the outcome of the recruitment process, the order of appearance matters in decision processes.

The idea of programmes and anti-programmes (competing attempts to create an actor-network) that can be explained using a 'tug-of-war' metaphor is well illustrated by stories told by Hernes (2005), Vickers and Fox (2005) and Helgesson and Kjellberg (2005).

Using a set of illustrations rather than one empirical case, Helgesson and Kjellberg (2005) explore a 'tug-of-war' between consumers and marketers, where successful resistance was not a result of a particular strategy and was never programmed. Studying the construction of power, the association of elements through which macro-actors are configured, paying attention to 'the diverse sounds of the silenced' and those who speak on their behalf. Elaborating the programme/antiprogramme dichotomy, the authors tried to switch perspective from centre to peripheral elements.

A few studies present interesting cases where macro-actors have an intention to construct other subordinate macro-actors. For instance, Mouritsen and Flagstad (2005) explore the attempts of Danish government to create another macro-actor – the Intellectual Capital project, financed by the Danish state from 1997 to 2002 as part of the industrial policy aiming ‘to create the firm of the knowledge society’ (Mouritsen and Flagstad, 2005, p.209). This macro-actor experienced problems with the construction itself and was ended as a result of political changes. According to the idea about the knowledge economy, the intellectual capital statement was supposed to function as a technology or tool for firms in the ‘knowledge society’, which is, being a ‘general discourse’ rather than an institution or organisation, appeared to be a fragile and illusive term, but nevertheless can be viewed as a possible macro-actor. The authors analyse the process of black boxing for the intellectual capital statement (which in turn could become a black box for the knowledge society), show how it was attempted to be made a black box, went through the series of transformations and how was abandoned later. As Mouritsen and Flagstad suggest, the problem was that intellectual capital was not a stabilised concept and its meaning was not clear, ‘neither firms nor state knew what intellectual capital was’ (ibid., p.212). It never became quite a black box although was envisaged as such (ibid.).

In another study Hägglund (2005) considers the case of an economic decline in a company, which is not only a macro-actor itself, but also an arena for other organisational actors. In the process of organising, which is shaped by various actors, macro-actors are created and destroyed. Using three explanatory frameworks for analysis of macro-actors – structural analysis, interpretative inquiry and ANT, Hägglund comes to the conclusion that only ANT can help to connect several organisational sites providing an understanding and explaining formation and stabilisation of several macro-actors in the company. Helping to open the black box of organising, ANT ‘focuses on emerging and potential macro-actors in the organisation and shows how they are formed in interaction between various local actors’ (ibid., p.266). Hägglund suggests seeing organising as a negotiation of stable connections, where the length and density of connections are important, and such approach might help to understand the process of stabilisation of competing organisational macro-actors in the company.

Studies that explore ANT as a methodological resource also refer to a concept of macro-actor. For instance, Warzynski and Krupenikava (2010) examine ANT as a leadership strategy for creating macro-actors (powerful networks) to foster innovation and social change. A study, based on the project around the Centre for a Sustainable Future (CSF) conducted in one of the universities, not only shows the creation of macro-actors, but also discusses in detail the application of ANT strategy by a group of students to this sustainability project (Warzynski and Krupenikava, 2010). By using network analysis they helped to strengthen and expand CSF's network and assisted CSF in establishing itself as a macro-actor; the students who were working on the project also transformed from a disparate group of individuals into another macro-actor for sustainable development (ibid.). Warzynski and Krupenikava suggest that a more comprehensive approach to understanding the needs, problems, and challenges of innovation and change and more integrated methodologies are required to explain creation of macro-actors for sustainable development (ibid.).

2.4.3. Heterogeneous engineering

As it was mentioned earlier, actor-network theory offers the notion of heterogeneity to describe projects and analyse situations where separation of human and non-human elements is difficult, it denies that purely technical or purely social relations are possible and makes no distinction in approach between the social, the natural and the technological. Strathern characterises the concept of network as summoning 'the tracery of heterogeneous elements that constitute that object or event, or string of circumstances, held together by social interactions'; such networks can be seen as hybrids imagined in a 'socially extended state' (Strathern, 1996, p.521).

From the ANT perspective, technological trajectories are also the product of heterogeneous contingency and there is nothing inevitable about the way they evolve (Bijker and Law, 1994). Studies of organisation, innovation and technological development are based on studying connections between heterogeneous actors enrolled within a network and how these actors exert influence over the trajectory of a network (i.e. technology development and innovation). During this process the actors do not shape technology apart from the social world; rather they are constantly defining and re-defining a sociotechnical world.

Further I would like to point to several studies that discuss the idea of heterogeneous engineering and their arguments that have implication for sociology of artefacts and technology, shaping an approach to the analysis of technological innovation.

First, it is necessary to mention the study of the development of the electrically powered automobile (VEL) in France in the 1970s by Michel Callon (1987), where he introduces the notion of ‘engineer sociologists’. His analysis suggests that engineers involved in the project were engaged in analysing and ordering social relations addressing social and technical problems simultaneously. According to Callon, the engineers were contributing to a debate between competing sociological interpretations of the future of French society. The plan presented for the VEL determined not only the precise characteristics of the vehicle, but also the social universe in which it would function. Therefore, they were simultaneously designing both a technology and social world in which it had a place.

The studies of Portuguese expansion and the ‘nautical revolution’ of the fifteenth-sixteenth centuries by John Law (1986, 1987), where he develops a notion of ‘heterogeneous engineering’, are remarkable. In his work Law provides an account of the precarious networks of global domination making a contribution to analysis of long-distance social control and heterogeneous engineering practices. The main idea is that ‘in explanation of technological change the social should not be privileged’ (Law, 1987, p.113). He argues that these processes and events can be only understood if the technical, the economic, the political, the social and the natural are all seen as being interrelated (Law, 1986; Law, 1987). Artefacts should be seen as forming an integral part of systems and as interwoven with social, economic and other elements. Moreover, the principle of symmetry is adopted for explanations for all components of a system that go to make up a heterogeneous network which allows treating them on equal terms (Law, 1987).

Analysing the materials of long-distance control Law looks at the types of elements that Portuguese brought together in their system and how these elements were juxtaposed forming a specially constructed and relatively stable structure (ibid.). Examining maritime and navigation techniques, he draws on Latour’s notion of ‘immutable mobiles’ and makes an argument about an ‘envelope of durable mobility’ for vessels which among others also incorporated astronomical context. Some of the elements in turn can be seen as manifestations of previous work, as simplified black boxes which being placed in an ‘envelope of other elements’ were capable to generate effects needed to sustain the structure (e.g., an astronomical astrolabe represented the ‘relevant distillation of generations of work in astronomy and instrument-making’; navigators who had special maritime skills were also the embodiment of previous effort and can be seen as black boxes from the standpoint of successful navigation) (Law, 1986, p.252, 254). Documents, devices and ‘drilled people’ were the key elements in a combination that led to the success. All these elements were potentially mobile and durable, put in ‘structured envelope’ and able to ‘act upon that structure’ (ibid., p.254). The theoretical claim made here is about the generation of a ‘structure of heterogeneous elements’ – a combination of texts, physical objects and people as ‘raw materials’ for those who want to exert power at a distance (ibid., p.255, 257). Heterogeneous engineers, or system builders, standing at the heart of networks, are not ‘analytically privileged’ and also are amenable to analysis – they are can be seen ‘as much an effect as a cause’, as a result of interaction between networks of forces (Law, 1987, p.132).

Law puts forward an argument that from the standpoint of the network an element exists in the system if its presence is felt by ‘influencing the structure of the network in a noticeable and individual way’ (ibid., p.131). Thus, the choice of network in focus is crucial – different patterns and structures will emerge and be seen from different standpoints. As such, the studies of heterogeneous networks for Law are based on principles of generalised symmetry and ‘reciprocal definition’ (meaning that actors can be only entities that ‘exert detectable influence on others’ and can influence the structure of network) (Law, 1987, p.132). Discussing the ideas of heterogeneous engineering Law (1986, 1987) does not see the social as privileged, and this approach is similar to a technological system approach (or system-building perspective) coming from the history of technology (Hughes, 1983, 1987).

Another well-known study that employs the idea of heterogeneous engineering and develops it further is a work by John Law and Michel Callon about engineering and sociology in a military aircraft project (Law and Callon, 1988). Discussing a development of a large military technology project (which eventually failed), Law and

Callon describe its trajectory from the initial idea to the cancellation of the project tracing the evolution of networks of heterogeneous relations and pointing to the contingency of this process. They warn against social or technological reductionism in analysis of technological change suggesting to consider both social and technical as jointly created in a single process.

According to Law and Callon, the proposed machine was part of the 'social theory' of those responsible for specifications for possible aircrafts that might fulfil the needs of the Royal Air Force: its size, shape, and specification reflected notions about the network of intentions, powers and capabilities of relevant national and international actors (ibid.). As such, they see the design of a system not only as purely technical but rather as a solution informed thoroughly by social considerations. The proposed aircraft could be seen as a 'putative sociotechnical network' – a solution to an interconnected set of political, bureaucratic and strategic problems. The authors also suggest a notion of a 'sociotechnical scenario' which represented proposals about the structure and distribution of both technical and social roles ('a plausible proposal for a revised network of both social and technical roles that does not rest on an *a priori* distinction between human beings and machines' (ibid., p.287)).

In this work Law and Callon put forward a thesis that local networks contain global network, or using a network vocabulary, that '*context is internalized in the object*' (ibid., p.296). Trying to identify strategies for relatively stable sociotechnical networks, they suggest that generating a 'negotiation space' could be one of them.

2.4.4. Power, irreversibility and stabilisation of networks

The ideas of power, irreversibility and stabilisation help to examine consolidation and the character of network ordering. In ANT order is seen as an effect generated by heterogeneous means (Law, 1992a), and the material heterogeneity of arrangements cannot be ignored (Law, 1991a). Any network is an effect of connections that constitute it. Studying associations of heterogeneous actors one can understand how networks become larger, more durable and more influential than others through enrolling both social and material actors, and where power comes from and how it exerted (Cressman, 2009).

Developing a translation model of power (Latour, 1986), ANT 'demystifies the power of the powerful' (Law, 1992a, p.320). Power in ANT is seen as a performative effect rather than something possessed by actors (Latour, 1986); it is taken here to be the effect or result of events and actions associating entities together rather than a set of causes in contrast to traditional theories which take power to be the cause of events (Latour, 1986; Law, 1992a; Czarnniawska and Hernes, 2005). The amount of power depends on the number of actors who enter into the composition and on durability of associations built between them (Latour, 1986).

For the analysis of power and robustness in networks in science studies the notions of irreversibility and stabilisation are important (Star, 1991). Exploring the heterogeneous processes of social and technical change and the dynamics of techno-economic networks[14] – the complex processes in which actors and their intermediaries weave themselves together, Callon discusses how actors are constituted and define each other within networks in the course of translation (Callon, 1991). He talks about convergence and irreversibilisation to explore the construction of a unified space for incommensurable elements and the longevity of these connections. Callon argues that these notions (convergence and irreversibilisation) can help to explain how different actor-networks, which are not even compatible, reach durable 'agreements' (ibid., p.142).

Callon explains convergence using the notions of alignment and co-ordination: 'the higher the degree of alignment and co-ordination of a network, the more its actors work together, and the less their very status as actors is in doubt'; the activities of actors fit together despite their heterogeneity (ibid., p.148). In other words, successful process of translation aligns and generates a shared space and commensurability (ibid.). The network as a whole would be capable of concentrating

[14] This term is used by Callon to describe a 'coordinated set of heterogeneous actors which interact more or less successfully to develop, produce, distribute and diffuse methods for generating goods and services' (Callon, 1991, p.133).

its efforts at a single point, although such a network is a limiting case as it requires a long period of investments, efforts and coordination (ibid., p.148).

Irreversibilisation is another notion suggested by Callon to explain the dynamics of networks and durability and robustness of translation. The irreversibility of a translation is a relational mater which is never finally resolved, as all translations can be reversible in principle (ibid.).

The more numerous and heterogeneous interrelationships between elements in a network the higher resistance to alternative translations. When all elements are inscribed in a 'bundle of interrelationships', attempts to modify one elements would lead to a general retranslation (ibid.).

The mechanism of 'normalisation' accompanies the irreversibilisation of translation in hybrid groups and operates by 'standardising and constraining actors and intermediaries'. This produces systemic effects, as elements can re-arrange themselves using well-defined elements which adopt compatible standards, and choices become predictable (ibid.). In Calllon's words, a 'network whose interfaces have all been standardised transforms its actors into docile agents and its intermediaries into stimuli which automatically evoke certain kind of responses', or, using a metaphor, 'the past engages the future' (ibid., p.151).

It is suggested that to challenge certain translation and establish new ones could be problematic, as it would be necessary to mobilise and enrol new alliances to undo the existing translations (ibid.).

Strongly convergent and irreversible networks become predictable and can be assimilated to black boxes or a 'punctualised nodes' in other networks playing the roles of actors or intermediaries (ibid., p.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., p.153).

Although in this paper Callon offers a method for describing networks and their asymmetries, not a theoretical framework for their explanation, he suggests that 'the more convergent and less reversible a network, the more the descriptions delivered by the intermediaries turn into explanations and predictions' (ibid., p.154). This means that a strongly convergent and irreversibilised network works and evolves in a regular manner as a function of a few simple laws, and its evolution can be described using a small number of variables or concepts. Contrary, a description of a divergent and reversible network 'has to cover all the details, since every detail counts' (ibid., p.155).

Susan Leigh Star in her essay on power, technology and the phenomenology on conventions tries to understand the nature of stabilisation of large scale networks (Star, 1991). She discusses, among others, problems of standards (challenges of standardisation) and invisible work. Starting with the question of stabilisation of networks ('how networks come to be stabilized over a long period of time'), she refers to earlier discussed work by Callon *Techno-Economic Networks and Irreversibility*, stating that some changes occur in large networks which are irreversible, no matter what their ontological status (ibid., p.40). This relates to the process of arrangements becoming stable in a community creating well-established structures and practices, which in turn can shape action of others by means of established conventions of use about materials, goods, standards, measurements, and so forth. It is suggested that working outside this set of standards or creating alternative standards may be expensive or even impossible, unless an alternative community develops for some reason (ibid., p.41). Pointing to the critical difference between stabilisation within a network or community of practice and stabilisation between networks, and differences between those for whom networks are stable and those for whom they are not, Star suggests that the set of conventions – a stabilised network is stable for members of the community of practice who form and maintain it, but it is not stable for non-members (ibid., p.42-43).

2.4.5. ANT perspective on renewable energy

ANT is often used to assist in the exploration and explanation of various socio-technical phenomena, such as technology innovation and organisation practices in different fields (e.g. ICT, health care, higher education, energy, sustainability).

For example, it was suggested that ANT can serve as a theoretical perspective for exploring the ecological order, environmental degradation and green organisation processes. Arguing for an interdependency network perspective, Newton (2002) indicates a possible research direction on ecology and organisations proposing that the sociology of order and networks, particularly the work of Michel Callon and Norbert Elias, would be an alternative perspective and basis for research in the field of green organisational studies. The argument here is that 'in both there is an emphasis that agency is best viewed from the perspective of interdependency networks, whether that of a single organisation or the dense, complex, and global interdependencies surrounding environmental degradation' (Newton, 2002). Newton supports Dobson's pessimistic point of view on the possibility of achieving consensus on environmentally far-reaching reforms. Criticising organisational writers who adopt an ecocentric approach, he argues that instead of shifting to strong green cultures it is more productive to research the configuration of interdependent networks that support or impede greening processes. In exploring this argument, he examines the interrelation between the concept of the actor and the networks that surround environmental degradation. Addressing the challenge of building global green networks, he indicates the application of ANT as a possible research direction on ecology and organisations.

The literature that includes explorations of the potential of ANT (solely or in a combination with other approaches) to analyse renewable energy projects and policy in the field is limited. The paper that needs to be mentioned is one by Galvin (2009) *Modifying Actor-Network Theory to Analyse the German Project of Photovoltaic Electrical Energy Generation,* where he tries to modify ANT to analyse the German Photovoltaic energy project. The interesting aspect of this study is its methodological positioning – the author suggests a composite analytical framework combining ANT and policy discourse approaches which he calls 'discursive actor-network theory enterprise' (DANTE) (Galvin, 2009). For Galvin various interplays of material and discursive factors help to understand the subsidy system for German PV. DANTE framework is used to perform critical analysis of the German PV project and to provide explanations for its peculiarities, pointing to inefficiency of this type of renewable energy ('a renewable energy technology that has failed'), which is mainly supported through subsidies – a consequence of the structuration and institutionalisation supported through policy discourse. It is also suggested that DANTE can be employed in analysis of other sociotechnical systems.

An application of actor-network theory to the analysis of wind energy and related participation process in the study by Jolivet and Heiskanen (2010) *Blowing against the wind – An exploratory application of actor network theory to the analysis of local controversies and participation processes in wind energy* is another example of renewable energy case, where ANT is used to analyse local controversies shedding light on the complex and political nature of planning a wind farm project. In this case wind farms are presented as 'a positive element underlining and humanizing the natural appearance of the Lentin fault'. Nevertheless, controversies occur (so called 'overflows') when local actors do not conform to managers' expectations (ibid.). Controversies here are considered as alternative efforts of competing networks of actors to 'frame' the reality and enrol others. During the consultation process actors adopt conflicting positions and develop their own interpretations of the project; designers in turn have to adapt these frames and change plans accordingly (ibid.). The practical basis for the public inquiry is provided by maps and visualisations which give a representation of future wind farms, location, visual impact, etc.

It is suggested that 'the participation process is difficult to comprehend without analysing the technicalities, as they are the subject of controversies and resistance, and this link between 'technicalities' and 'socialities' of the processes is difficult to grasp' (ibid.). As such, materiality and physical objects are central for 'siting' process which is seen as a plan for materialising technology with maps and other visualising artefacts as central instruments for discussion.

Another study that employs ANT approach and the concept of translation is a paper by Ariani and Yuliar (2011) where they explore the bio-fuel development trying to make sense of the current diffusion of bio-fuel innovation which is still very limited in Indonesia. The authors try to understand the bio-fuel development trajectory by seeking to disclose a variety of elements that shape its trajectory (Ariani and Yuliar, 2011). They also offer a concept of 'qualculation' for the analysis of technological innovation. Specific patterns of qualculation, ‘proliferation’ and ‘rarefaction’, are followed in analyse of the diffusion of bio-fuel innovation.

The studies discussed above are examples of how ANT has been translated in renewable energy research. It is suggested that the ANT concepts of translation and heterogeneous networks can be the most useful for analysis of renewable energy projects. However, these studies are limited and do not consider marine energy and related technologies.

2.5. Content/context dichotomy in STS

In this section I would like to expand the discussion of context/content dichotomy which was mentioned only briefly discussing ANT, and to focus on contemporary approaches to understanding the concept of context and the question of the emergence and transformation of context. As policy and regulations are often referred as a framework or context for the case study, it is necessary to decide which approach (or a combination) fits the theoretical basis of this research and can be adopted for analysis. Thus, this literature is useful for the purpose of further analysis of policy issues and relevant empirical data which is based on the idea that the distinction between context and content is being constantly negotiated and generated by actors; this distinction depends on a perspective (individual or emerging through collective deliberations).

The problem of context and content has been a subject to debate in STS and other social sciences (e.g. anthropology). It is suggested that ‘social science depictions work by mobilizing and defining contexts’ (Law and Moser, 2011).

To understand the concept of context it is worthwhile to look at the etymology of the word ‘context’. The word ‘context’ has a Latin origin and is derived from the word which means ‘to weave together’, ‘to interweave’ or ‘to join together’ (Dilley, 2002, p.441-442). The common definitions of the notion ‘context’, pointing to the connection between the object and its context, emphasise the role of the latter in understanding (and interpretation) of the object under consideration. According to the Oxford Dictionary, context can be defined as 1.the circumstances that form the setting for an event, statement, or idea, and in terms of which it can be fully understood[15]; or 2.the circumstances that form the setting for an event, statement, or idea, and *in terms of which it can be fully understood and assessed*[16].

The conventional approaches to context in social sciences treat it as 'a 'given' or a self-evident construct', something that is not questioned but simply taken as preassembled, 'as it were' (Dilley, 2002, p.439). Dilley argues that context and the process of contextualisation in social anthropology has been seen as unproblematic, a real phenomenon, isolated and formally described. In Law and Callon's view, the standard approach to the context-content dichotomy is a relatively clear-cut division, although some negotiations along the boundary are possible (Law and Callon, 1989).

The problem of the construction of context is addressed from a position of cultural and social anthropology as a key analytical concept, which crosses the boundaries of different disciplines (anthropology, linguistics, history, philosophy, etc.)[17]. A shift in approaches led to recognising contexts as social constructs which are being generated and negotiated in the course of social interaction (Dilley, 2002). Contexts indicate levels of analysis as well as the substantive focus of analysis (ibid.).

In Augier et al (2001) it is suggest that the context is not a static entity ('just there') but an emerging phenomenon. Context can also be seen as an individual construct based on the individual's previous experience, and it emerges and transforms during acts of interpretations (ibid.).

Dilley argues that 'context is itself problematic, and is a result of prior interpretations' (Dilley, 2002, p.439). One can think about context in terms of connections and disconnections, seeing context as a set of relations and not self-evident thing in itself. It is also a relational thing as 'contexts are set of connections construed as relevant to someone, to something or to a particular problem' (ibid., p.440). This

[15] Oxford Dictionary (En-En) (для ABBYY Lingvo x3)
Oxford Dictionary of English, Revised Edition. © Oxford University Press 2005.
[16] Oxford American Dictionary (En-En) (к версии ABBYY Lingvo x3)
New Oxford American Dictionary, 2nd Edition. © 2005 by Oxford University Press.
[17] See, for example, the collection Dilley, R. (ed.), 1999. *The Problem of Context*.

process provides explanations and interpretations for the object connected, and at the same time separating the object and its surroundings (context) from the rest of the environment which is considered to be irrelevant. Another interesting point is made about the connection of context with knowledge: people construe contexts from their own bodies of knowledge, including and excluding things, drawing a line in accordance with a sense of relevance (a process of power). The claim about context as 'an articulation concerning a set of connections and disconnections thought to be relevant to a specific agent that is socially and historically situated, and to a particular purpose' represents the perspective on the construction of context in social sciences to date (ibid., p.454).

STS scholars analyse the concept of context and the context/content dichotomy while developing the actor-network theory-inspired approach (Callon and Law, 1989). It is suggested that actor-network theory emerged as an 'anticontextualizing' approach with the emphasis on 'actor-networking' as the way in which the transformation of interests and material and social reality were enabled (Asdal, 2012, p.5-6). Not questioning the existence of the context and content divide in principle, they put forward an argument about the symmetrical approach to content and context, suggesting that both content and context are 'jointly created in a single process' and that context is 'internalized in the object' or, in other words, 'the local network contains the global network' (ibid., p.296).

Denying the standard approach to the context-content dichotomy as a relatively clear-cut division, Law and Callon (1989) in their turn argue that this distinction (between context and content) is negotiated (and renegotiated) by actors themselves (not legislated by analysts). Law and Callon suggest 'to trace the sociotechnical networks that are put in place by actors whether these pertain to content or to context' (Law and Callon, 1989, p.58).

The idea of dissolving a priori categories of context and content derives from one of the basic principles in ANT – that of generalised symmetry, which suggests that 'the focus of analysis should be the tactics and strategies adopted by translators in the process of designing sociotechnical networks and imposing these on others' (ibid., p.77-78). Consequentially, attention is paid to the process of translation and construction of a network, not to the boundaries and the distinction between content and context. Law and Callon argue, that this distinction is generated locally between relatively dependable performing networks and ‘the more expensive investments of form that are put into place within the negotiation space created by the relative dependability of performing actors’ (ibid., p.78). Successfully translated actors (mobilised without contradiction and reduced to ‘stable and predictable entities’, monoliths), in Law and Callon’s view, constitute the context of a particular project as they become part of the background. By contrast, complex and intractable networks that still require translation are the focus of attention and constitute the content of the project. Thus, the context itself is understood (which might include social and economic relations etc.) as something beyond the ‘negotiation space’, and the mobilised actors create a context for the growing network (macro-actor).

A recent approach to analysis of context in ANT considers how the making of context relates to political agency and intervention (Law and Moser, 2011). The main argument here is that ‘to depict the world is to assemble contexts and to hold them together in a mode that may be descriptive, explanatory, or predictive’ (ibid., p.16). Variable interpretation and ambivalence of policy, its multiplicity, inconsistencies in implementing policy, and even resistance to policy, according to Law and Moser, describe the context of complexity, showing that the context is ‘purely social’. Although there are many ways of assembling contexts and holding them together, they ‘belong together’ (ibid., p.18), and a single narrative context can be generated to assemble different bits of the world. Law and Moser believe that it does not pose a problem for description, but has political consequences. Their assumption is that ‘there are many ways of assembling contexts and holding them together’ (ibid., p.17), nevertheless, a single framework can be used to describe the world which means that ‘a single narrative context can be generated’ (ibid.) and all different bits and pieces can be assembled together into an overview for practical purposes.

Having noted some differences that exist among researchers from different schools of thoughts, there are clearly common arguments that context is a non-static phenomenon and a social construct.

2.6. Research questions

For this thesis the key research areas are the emergence and growth of an actor-network and the construction of a macro-actor around a technological project, Wave Hub, with different meanings attributed to it, its boundaries and its credibility. Problematisation also involves raising questions about the politics of expertise, uncertainty and unmet expectations.

The research questions are formulated as follow:

1. To what extent, and in what sense, can policy be understood as an element of an actor-network, not merely a context? Does the ANT approach help to develop a new perspective for conceptualisation of policy?

I will start my investigation with exploring potential of actor-network theory for the analysis of development processes and controversies in wave energy sector, in particular, reconstructing a historical narrative of a wave energy project analysed as a macro-actor, building what is termed a ‘possible history’ of the project. I will pay special attention to the controversial aspects of its development and political dimensions of this process. The main purpose of exploring the emergence of a macro-actor and examining numerous controversies about its design and destiny is to investigate the idea of policy as an actant. Thus, the central research question that I will investigate is to what extent, and in what sense, policy can be understood as an element of an actor-network, not merely a context. This question helps to build a critical discussion around the evolution of an actor-network with policy as its active element and critically assess to what extent this approach might help to understand the destiny of a technological project and to re-read the history of the project through the proposed ideas of policy as an actant. From the perspective of symmetry in heterogeneous networks I will assess the role of policy as an actant in a network and examine the relationship between political decisions and the development of Wave Hub, as well as a possible reverse effect that the project might have on policy and regulation in the field, and whether the way the project has been implemented can be seen as an indicator for assessing renewable energy policy and related regulations, their readiness for technical change in the sector. I also aim to explore to what extent the flexibility of the project might be reduced if the policy aspirations become a part of the early discourse on Wave Hub and could determine its vision and design, creating constraints for technical choice, and whether it could affect the credibility of the project.

2. How is the credibility of the technological project as a macro-actor constructed? How can the analysis of the controversies help to problematise the idea of credibility in relation to the construction of expectations of the project? How is the notion of failure constructed, and what is legitimised as possible causes of failure and possible solutions?

The politics of technical decisions, and in particularly what stands behind the conceptual design of Wave Hub is interwoven with the question of credibility of the macro-actor, which is another key research area for this study. The analysis will start with the question of how the credibility of the project was constructed and how it has been proved during the development process. This involves exploring whether the claims about the strategic nature of Wave Hub helps to build its credibility and perception by different actors. I will explore such important aspects of credibility of Wave Hub (a macro-actor) as the public 'face' and presentation of the project, the official discourse justifying the idea and its implementation; the different meaning attributed to Wave Hub (the perception of Wave Hub by different actors and social groups), and its symbolic capital. It also allows me to develop further the argument about policy as an actant and to consider its performance in constructing credibility of the project (promissory role of policy discourse). Another aspect/subquestion that helps to problematise the idea of credibility of Wave Hub is legitimate decision making at different stages of the project development. I will examine the process of decision making throughout the project development, the construction of notions of 'failure' and 'mistakes', as well as lessons learned out of this process, changes in design and its justification and explanations. This leads to the third research question which looks at the construction of credibility of scientific and other kinds of expertise in relation to Wave Hub.

3. How is the project construed as a credible expert endeavour? How was expertise performed in the case of Wave Hub and what was the role played by different types of expertise for credibility-economy of the project?

The credibility is closely interwoven with the politics of expertise. Exploring the question of credibility of Wave Hub as an innovative pioneering technological project that aims to facilitate the development and deployment of wave energy technologies, I will examine the problem of using different types of expertise and the politics of expertise in the case of Wave Hub. From the very beginning Wave Hub was perceived as a ‘challenge for experts’ due to uncertainties and controversies surrounding it. This makes the project an interesting case for studying the politics of expertise surrounding it and the experts themselves, their status and self-(re)presentation. I will explore how the expertise is understood and performed in the case of Wave Hub and for which purpose, how the expert knowledge and the expert status are constituted. I will study the contestation of expertise, its categorisation and discuss the assessment of expertise within the community and by outsiders. I will analyse various forms of collaboration formed around Wave Hub, but also antagonism which was revealed between different groups of experts.

Chapter 3. Methodology

3.1. Introduction

This chapter aims to consider methodological concepts which have influenced my approach to methodology, political and ethical issues, as well as practical aspects of data collection, and the challenges and choices I faced in the process of data analysis. It also includes some reflections on conducting my fieldwork.

In this thesis, I present a qualitative study with some ethnographic elements which explores the dynamics of socio-technical change associated with construction of a wave energy project. There is an established tradition in STS to bring in qualitative analysis to develop in-depth understanding of socio-technical change. Actor-network theory and discourse analysis are two research traditions in STS which are perceived as being fairly distinct, yet I will argue that both have a potential to work together in the analysis of Wave Hub.

The materials I will be drawing on consist of 27 interviews I conducted during the period from October 2010 to July 2011, research papers, articles and documentary data (studies, reports, legislation) partially provided by participants and partly obtained from open sources, such as official websites and press/media.

3.2. Research strategy and objectives

3.2.1. Methodological positioning of the study

The philosophical aspects of research are important for every study, as the range of methods and techniques that are used in research should not be seen as entirely free-standing, but should be subordinated to the considerations of purpose and philosophy of the research (Easterby-Smith et al., 2000). Furthermore, it can help to clarify research design, which means the overall configuration of a piece of research rather than simply the methods by which data is collected and analysed.

Although the research approach in this thesis is seen as mainly inductive and the research process started from an empirical basis, theoretical preconceptions were not rejected and provided a ground for developing a line of inquiry and formulating research questions. The design of this research project provides a possibility to alternate between (previous) theory and empirical facts for data interpretation and analysis, where both are successively reinterpreted in the light of each other.

In the literature one can find the suggestion that the nature of the phenomenon to be explored determines the choice of research methods (Flick, 2006). To what extend is that justified? Study of technologies is an open space for trying out various methodological frameworks. Wave Hub offers an interesting case study where I could apply this approach.

The study presented in this thesis has the features of qualitative research. Qualitative research is oriented towards analysing concrete cases in their temporal and local particularity and starting from participants' expressions and activities in their local context (Flick, 2006). Qualitative techniques are not concerned with measurement and various dimensions, thus they tend to be less structured than quantitative ones. It makes them more responsive to the needs of respondents and to the nature of the subject matter (Walker, 1985).

In my research I came across some quantification when studying technical aspects of the technological project and expert discourse. In STS we tend to ask questions about quantification and its utility. In this study I have turned quantitative issues into a topic for discourse analysis, e.g. studying scientists' repertoire.

The main perspective from which I explored the object of study is social constructivism. Although this approach can be complex and varied representing a widespread body of tenets and theories, all of them seem to derive from Kant, although the drive for construction belongs to the twentieth century (Hacking, 2001). The basic assumption here is that reality is not something naturally given, it is socially constructed, including through research. In Hacking's words, the existence or character of a phenomenon is not determined by the nature of things and it is not inevitable, as it is brought into existence or shaped by social events, forces, history, all of which could well have been different (Hacking, 2001). The approach is not particularly theory-oriented; rather the focus is on the 'disclosure' of how social phenomena are socially constructed (Alvesson and Sköldberg, 2009).

3.2.2. Multiperspectival analytical framework

The research topic in this study is complex, concerned with processes, relationships and interactions of different actors. It requires a multiperspectival composite framework as a methodological approach to data collection and analysis. In this section I discuss the analytical framework that I considered the most suitable way to approach the analysis of socio-technical change in relation to renewable energy and to answer the research questions using the data available.

3.2.2.1. ANT as a methodological strategy

Actor-network theory (ANT) is a variation of social constructivism (or 'co-constructionist' as it seeks to identify how relations and entities come into being together (Murdoch, 2001))[18]. It represents a second wave of social constructivism, which assumes that non-human actors (e.g. technical artefacts) have a life of their own and can play an active role in the construction of heterogeneous networks (probably, the most provocative aspect of ANT). ANT can be considered not only as a theoretical tool or a description of theory, it can be referred as a strategy (Neyland, 2006a). As it is important for ANT to follow actors themselves[19] (Latour, 1987), the methods used for this purpose include interviews, ethnographical observations, and work with different kind of 'inscriptions' (Latour and Woolgar, 1986) like texts, databases, etc. (Alvesson and Sköldberg, 2009). For my research it is important that in ANT 'technical entities are given an equal status with social entities' allowing a technology to 'enter the story as a more prominent character' (Neyland, 2006b, p.372-373). It is suggested that 'network imagery offers a vision of a social analysis that will treat social and technological items alike', where any entity or material can qualify for attention (Strathern, 1996, pp.522-523). For example, in my empirical chapters I consider Wave Hub and other non-human actors (i.e. waves, policy) as actants. As such, ANT can be seen as the best strategy for the analysis of a technological project which is perceived in this study as an emerging and evolving

[18] An actor-network theory and its role in STS research were discussed in detail in Chapter 2 Literature review.

[19] This slogan should not be understood literally – it means that following actors sociologists take their categories, see the world through their eyes and take on the point of view of those whom they are studying (Law, 1991b, p.11).

heterogeneous network. In the literature review I outlined some theoretical approaches and concepts (e.g. a macro-actor and blackboxing) and critical questions for ANT. In this chapter I will focus on methodological premises for ANT-informed research.

There have been deliberations about the status of actor-network theory as a method for social research that started with its naming (‘fixed tag’). Discussing the ‘label’ of ANT, Law (1999) has suggested that due to its labelling ANT has been turned into a ‘specific strategy with an obligatory point of passage’, a ‘fixed theoretical location’ which is performed in part by its naming (p.2). Arguing against fixity and singularity, Law calls ANT ‘diasporic’ as it has spread and has converted itself into a range of different practices (ibid., p.10). It also can be seen as a multiplicity – ‘ANT multiple’ as ‘different versions of ANT exist, which entail diverse theoretical, analytical, methodological, and empirical implications and commitments’ (Gad and Jensen, 2010, p.75-76). Therefore, a shift from a fixed approach to an ambiguous and contingent strategy was suggested (Neyland, 2006a).

ANT became an important component of the composite analytical framework in this research. It was the main strategy for constructing the first analytical model around my case study. An actor-network theory methodological suggestion to follow the actors (Latour, 1987) became the main conceptual methodology for data collection and analysis.

Some discursive themes are overlooked in STS. But is it so uncomplicated to tell a story about a technical project and its development? A method of ‘literary description’ that helps to create a ‘polyphonic narrative’ recovering all the relevant details is the main approach for dealing with networks in ANT analytical discourse (Callon, 1991, p.152). Excessive simplifications, in Callon’s words, can betray the state of the network, and ‘it is better just tell a story!’ (ibid., p.152).

I rely on an ANT approach constructing a narrative known in anthropology as a ‘thick description’ (Geertz, 1973) in one of the empirical chapters, where a possible history of the case study is discussed from the actor-network theory perspective. I also explore the extent to which an ANT approach allows me to problematise the level of analysis (micro/macro distinction) in exploring policy as an actant and to re-think the possibilities for analysing it from a new perspective in one of the empirical chapters (Chapter 5 Policy as an actant: from scale to agency). Employing the concept of a macro-actor, I question commonly assumed *a priori* distinctions between micro and macro and of an idea of ‘macro context’.

I start my data analysis drawing on the concept of a macro-actor which has been elaborated in actor-network theory (Callon and Latour, 1981) to analyse a technological project. In analytical discourse macro-actors are described by identifying relevant actors (human and non-human), tracing the evolution of an actor-network, providing detailed narration based on data available to a researcher. Examining the process of its creation, I paid special attention to the controversies and negotiation processes throughout the project’s evolution, and the contingencies that condition a project’s success or failure. To study a macro-actor also means to study the relations between various actors (not solely between humans), the involvement of different groups and the associations that they form and which become the basis of this construction (a macro-actor). The approach I adopted to try to ‘open up the black box’ (Latour, 1987) of the macro-actor was to attempt to understand how it appeared in the eyes of my respondents and, if possible, to interpret diverse and ambiguous accounts.

Although, as suggested by ANT analysts, analytical networks are theoretically without limit, in practice, heterogeneous networks are cut at some point (Strathern, 1996). In Strathern’s words, ‘the extent of a homogeneous network <...> appears to be bounded by the definition of who belongs to it’ (ibid., p.524). Deciding on insiders and outsiders, those who belong to the network and what can be relevant to the discourse around the case study, the participants can sustain a ‘difference between internal and external flows’ (ibid., p.531). This can be done using proprietorship or other principles of social organisation which are based on the notion of relatedness (ibid.). But as fairly noted by Strathern, ‘analysis, like interpretations, must have a point; it must be enacted as a stopping place’ (ibid., p.523). The researcher can cut the network by necessity, and it is assisted by practical conditions as well as intellectual considerations relating to the aims of research (Gad and Jensen, 2010).

My participants, as well as I as a researcher, were actively engaged in defining the boundaries of a macro-actor. Essentially, by recognising themselves as parts of a network in a conventional social sense, they were constantly doing ‘boundary work’[20] (Gieryn, 1983), performing a delineation of different actors and groups within a macro-actor. This delineation was consequential for the production of new knowledge, the construction of credibility and various systematisations (e.g. various expert groups and ‘expert hierarchy’).

The boundary work was performed through respondents recommending other potential respondents or rejecting my suggestions for further interviewees, allowing or not allowing me as a researcher to dig into the corporate culture of their organisations and various management issues, and sometimes by going beyond the proposed scope of the research, suggesting additional information (e.g. papers, reports etc.) which in their opinions could be relevant to this research and/or to the case study (Wave Hub). At the end, the boundaries of a macro-actor appeared to be a joint product of the participants’ and analyst’s discourse, turning a macro-actor into an analytical hybrid.

Discussing actor-network theory as a methodological strategy employed in this research, it is necessary to point to some limitations of ANT which made this strategy insufficient on its own for my research.

As was discussed in the literature review, the apparent complexity of ANT has led to some criticism for insisting on agency of nonhumans, its ‘amoral’ position, descriptive nature and lack of explanations for social processes. The critiques of ANT also often come from its problematic strategic status and its materialisation into an ‘enduring theoretical strategy’ which looses necessary flexibility and ambiguity (Neyland, 2006a, p.30). Theoretical limitations are the result of ANT’s fixed rigidity as its naming, transportability and black boxing as a ‘specific strategy that made it less contingent to the subject of analysis’ (ibid., p.38). One of the founders of ANT, John Law argued that ANT achieved a problematic status as a fixed strategy or, in other words, it is ‘excessively strategic’ (Law, 1999, p.6).

[20] In the empirical chapters I will look at instances of boundary work in participants’ accounts.

As one of the possible moves, it was suggested that ANT could focus more specifically on shifts between general declarations of ANT and the local, contingent, and messy application of ANT. Through this focus, ANT could act as a means of constructing a so-called 'theoretical flow' (with human and non-human entities drawn together into fluid relations) (Neyland, 2006a, p.42). Neyland (2006a) calls for a shift in focus to enable theoretical accounts produced by ANT to form a flow, which would offer an opportunity for multiple connections to be drawn together, connections that could dispute the content of the flow, question it, redirect it, and reassess it. This may generate a 'decentered actor-network flow without a single point of passage with more focus on the moves made by the entities' (ibid., p.42-43).

Besides its excessively strategic nature, ANT is also criticised for keeping to pure descriptions with no explanations entering the picture, for the lack of theoretical preconceptions, being sceptical about the idea 'let actants speak' since 'the research subjects know better than the researcher what goes on' (Alvesson and Sköldberg, 2009, p.33).

It is not surprising that analysts have often encountered a methodological discontent with ANT (e.g. Neyland, 2006a, 2006b; Murdoch, 2001), and a selective and utilitarian application of ANT is used by some of them (e.g. Newton, 1996). For example, Murdoch (2001) argued that in rejecting the discursive resources of traditional sociology, it is problematic for ANT to reach a conclusive understanding of the social forces that often determine how heterogeneous sets of socio-natural relations are constituted. Neyland (2006b) also noticed that in ANT 'little detail is offered on the deployment of particular strategies for producing accounts or developing forms of discourse' (Neyland, 2006b, p.372-373).

For my own research, ANT seemed to be analytically insufficient in light of other questions raised by my empirical work, such as questions regarding the construction of credibility and the construction of expertise in relation to a technological project. The limits of ANT are that we as analysts have to choose the accounts to describe the trajectory of a project (to build a historical narrative) which leads to the judgements of their relative validity. As such, the ANT approach could not satisfy thoroughly the requirements of my research and needed to be enriched with another approach – discourse analysis, and in particular a version of it that was developed within STS in studies finding variations and inconsistencies in scientists' accounts.

3.2.2.3. Developing a composite framework

The analytical framework employed in this study is based on the suggestion that ANT and discourse analysis can be both usefully deployed as theoretical strategies. Further I will discuss how they can be deployed methodologically in a combination that will allow for the development of data analysis in this study.

As suggested in the methodological literature, combining discourse analysis with non-discourse analytical perspective may be able to provide a 'fuller, and more explanatory perspective on the question under investigation than might be provided with just the one single perspective' (Paltridge, 2006, p.216). Moreover, as Phillips and Jørgensen (2002) argue, a multiperspectival framework formed by a combination of different theories and methods is well suited as a methodology for social constructionist discourse analysis. In part this is because of constructivism's 'inherent *perspectivism*': different perspectives demonstrate that the social world can be understood and constructed in various ways, where each perspective produces a particular understanding of the phenomena under study casting light from different angles and taking more account of the complexity of the phenomenon (Phillips and Jørgensen, 2002, p.154-155).

Discourse analysis, itself, is not just one approach, but a series of interdisciplinary approaches that can be used to explore many different social domains and can be applied in many types of study. Essentially, discourse analysis examines the patterns that people's utterances follow when they take part in different domains of social life (Phillips and Jørgensen, 2002). It is considered as anti-realist and constructionist – denying that there is an external reality awaiting a definitive portrayal by the researcher, it places the emphasis on the 'versions of reality produced by members of the social setting being investigated and on the fashioning of that reality through their renditions of it' (Bryman and Bell, 2007, p.536). For the purposes of my study, one of the strengths of discourse analysis is that it can reveal some aspects of technological development that, for example, policy analysis would not accommodate. It is widely used as a methodological strategy for qualitative studies in STS proving that there are alternatives to understandings of technological developments based on technocratic vision of technology and innovation. It is noted that in the sociology of scientific knowledge, that gave rise to STS, the analysts focused on ‘the explication of the organization of scientific accounts, the nature of the linguistic and argumentative resources which scientists deploy, and the consequences of particular accounting techniques’ (Potter, 1988, p.38).

There have been attempts in literature to develop a conceptual framework for analysing large complex socio-technical systems (e.g. renewable energy projects) where the use of one type of explanations or perspective would be unsatisfying.

For example, Murdoch’s (2001) suggestion of conducting analysis from both perspectives – ANT and discourse analysis in ecological sociology is based on critique of symmetry in ANT: in his opinion, human actors possess powers of reflection (through language) which can provide motive forces for action, and thus the distinction between humans and non-humans, considered within the same frame of reference, also needs to be assessed. This critique is reminiscent of Callon’s discussion of the market test for ANT where he introduced the notion of ‘homo economicus’ to highlight human agency in market relations (Callon, 1999).

In an attempt to simultaneously trace two types of influence: human/technological interactions and social influences emerging from relevant discourse, Galvin (2009) tried to modify actor-network theory for the analysis of the German project of photovoltaic electrical energy generation, suggesting a composite analytical framework combining ANT and policy discourse approaches, building a bridge between the two. The German PV project, in Galvin’s view, can be perceived in two ways – as an actor-network and as a product of policy discourse, ‘formed and shaped by the influence of human beings acting in response to socially constructed views of the world’ (ibid., p.3). Drawing ANT and policy discourse approaches together to analyse a failing socio-technical system, the author suggested a model called ‘discursive actor-network theory enterprise (DANTE)’ (ibid., p.12).

My methodological approach is similar to Galvin's DANTE, although for answering different research questions I take different methodological stances rather than combining them in a hybrid one. It seems to be analytically useful to employ one strategy or another depending on the purpose of the analysis and be flexible in addressing research questions.

Construction of a macro-actor goes beyond the task of producing a single (or even multiple) description of the project. My case study consists of several narratives. For example, a historical narrative, 'policy as an actant' narrative, a narrative of politics of expertise, and a credibility narrative. Indeed building a historical narrative is problematic in itself. As a researcher I was confronted with the need to be selective about the accounts; I had to make judgements about utility and appropriateness of the accounts. Nevertheless, this variability of accounts was interesting to explore. It became important for me to expand this line of inquest (i.e. variability), so I tried to turn it into a research question, exploring the construction of credibility of a macro-actor.

In other words, I would suggest that the complex analysis of a macro-actor (a concept employed for analysis of a case study) can raise visions of other possible lines of inquiry and research questions. Exploring some issues that go beyond 'traditional' ANT analysis might bring new insights. Nevertheless, these different lines of inquiry produced by different methodological strategies co-exist in this particular case study.

In summary, it is because the research questions raised in this study do not represent a single line of inquiry, that a composite analytical framework combining ANT and discourse analysis is seen as desirable. Although ANT is valuable for helping to open up the black box, on its own seems insufficient to answer most of the questions beyond the descriptive narrative due to some limitations discussed above. Discourse analysis enables the researcher to overcome the limitations of ANT and to explore a technological project in its various manifestations as a macro-actor (or an actor-network) and as a product of relevant discourse (a discursive construct). Both approaches can offer the means for the analysis of complex technological systems, which can be conceived as actor-networks that comprise various human and nonhuman elements and hybrid complexes produced as a result of interactions between them.

To take the analysis further, to enrich the understanding of a technological object as a social construct and to deepen the analysis of the discourse produced around it, I examined the participants' accounts to understand the constructive and functional dimensions of the discourse (though I do not pay close attention to the linguistic features of accounts).

A discursive factor cannot be dismissed in the analysis of success or failure of a technological system or innovation. A rigorous understanding of discourse and how it was constructed is needed to understand the various visions belonging to different actors and what stands behind such variability. The starting point could be that, applying Gilbert and Mulkay's (1984) words, there are no neutral and disinterested actors. The accounts cannot be taken at face value as accurate descriptions (Potter and Wetherell, 1987). As a result, a researcher often has to deal with a multitude of divergent and sometimes conflicting voices of participants (Gilbert and Mulkay. 1984). When this variability is not just a 'methodological nuisance' but an 'intrinsic feature' of the discourse, an analyst needs to be more sensitive to 'interpretative variability' of accounts and to explore it trying to understand why different versions are produced (ibid.). In other words, instead of resolving the variation between accounts the researcher tries 'to make that variation a way into analysis' (Potter and Wetherell, 1987, p.64)[21].

As variability is more than a 'methodological nuisance' (ibid.) in this case, it needed to be explored, especially in light of research questions about construction of the credibility of a technological project and expertise formed around it. The distinctive feature of the discourse analysis employed in this study is that participants' discourse is treated not only as a resource (source of data) but as a topic in itself. Discussing the case study, the participants were constructing different versions of the technological project (an object), its features and related events; these versions

[21] The literature suggests how to suppress account variability, e.g. through restriction, gross coding and selective reading (Potter and Wetherell, 1987).

also demonstrate their evaluations of the object and related issues. The notion of success of failure can also be understood through the discourse of the participants' conflicting accounts of the evolution of a technical system.

Eventually, I made a choice not to streamline the narrative but rather to highlight possibilities, advantages and disadvantages of the research approaches I explored.

Besides account variability in regard to various events in the project history and explanations behind them, I had to deal with so-called 'theories' of how my respondents would behave in certain circumstances. It was common in the fragments of interviews where various critical statements were made regarding the project fulfilment and the competence of those involved. When suggesting alternatives to the path that was undertaken, the respondents were presenting their versions of reality (interpretations, imaginations) constructing their own credibility and making the critique of others sound sharper.

While the ANT approach helps to build a 'thick description' of a technological project which was perceived as having various degree of success considering failures and shortcomings ascribed to it, the analysis of the accounts, their variability and functional dimensions allowed me to explore the construction of credibility of a technological project (including the construction of expertise around it), investigating a macro-actor in its various manifestations.

3.3. The politics of research

3.3.1. Political character of research

There are a number of factors that might influence the research questions and the direction of research including the subject of study, the context of research, the researcher's position, academic community, etc. (Easterby-Smith et al., 2000).

It is believed that 'social science is a social phenomenon embedded in a political and ethical context' (Alvesson and Sköldberg, 2009, p.11). The subject of study (the problem or issue to be considered) and ways to explore it correlate with existing social conditions, supporting (reproducing) or challenging them. The way in which reality is represented and interpreted might countenance different social interests. Alvesson and Sköldberg (2009) highlighted these dimensions, noting that the interpretations and the theoretical assumptions on which the research is based are not neutral but are part of political and ideological conditions which they also help to construct.

Some commentators use a notion of 'the politics of research', drawing attention to the power relationships between the individuals and institutions involved in the research enterprise, and strategies adopted by different actors which have certain consequences on others (Easterby-Smith et al., 2000, p.44). It is argued that power and political issues are significant even when they are not obviously present (ibid.). Ideologies, personal interests (including those of the researchers), power differences and ethical dilemmas are all essential elements that determine the political character of research (ibid.). Thus, we need to be alert to the use of the dominant narratives by participants (e.g. in energy-related sectors these are low-carbon economy, green energy, energy efficiency etc.).

The political-ideological issues are important not just in terms of research questions and ways to approach them, but also for interpretation process. As long as interpretation of data does not take place in a neutral, apolitical, ideology-free space, it is also subjective. Thus it is important to bear in mind that how reality is represented and interpreted depends in large on the researcher's views and values. Obviously, it is not necessary for the researcher to abandon her political convictions, if they do not direct a research towards political goals or practical interests and do not distort the findings (Hammersley and Atkinson, 1995).

Different interpretation possibilities, often introduced as neutral and rational, are brought out by various paradigms and concepts, research and political interests (Alvesson and Sköldberg, 2009). These can be paradigms and concepts that dictate the aims of research, justify its utility and prove its validity, for example, a low carbon economy or a broader concept of sustainable development.

In this research the choice of research questions and a case study was partly influenced by increased interest in renewable energy and the more general theme of sustainability in its various dimensions (e.g. organisational aspects). The interest in renewable energy developments is driven by number of factors including the concerns about climate change, related environmental issues, availability of resources, energy security, etc. There is an explicit political support in the area and ongoing debates at all levels which had a certain impact on this study.

Often renewable energy projects are dynamic, include quick succession of expertise associated with them. They are commonly described as newly emerging technologies having foreseeable potential for resolving various economic and social issues. Another factor that influenced the direction of my research derived from my interest in exploring potential of new methodological approaches to study renewable energy, in particular, in examining the potential of ANT to study wave energy project.

An important aspect of the politics of research is the interests of different social groups whose voices are represented in this study, and the different communities this research addresses (STS community, renewable energy and policy community). The interest of those participants who wanted to be heard and, probably, to deliver their views on various issues through participating in this research project can be partly addressed by means of publications and other forms of public presentation of the materials that were obtained (e.g. conferences, workshops etc.). Nevertheless, it would be naive to expect that the final outcome of this study would meet the expectations of all parties, as it obviously involves more than simple reproduction of the data collected, but represents a result of an analytical work done by a researcher including her personal perspective and interpretation of the data.

3.3.2. Ethical considerations

Politics and ethics are related issues. Ethics also has much to do with reflection and sensitiveness. It is believed, that researchers face ethical issues in every stage of the research process as a sort of dilemma (Flick, 2006). Ethical considerations are related mainly to questions about how to protect the interests of those involved in a study.

It is a common practice for social science research to rely on the principles of informed consent and of voluntary participation as preconditions for participation.

Confidentiality is also an important issue and includes the inability to identify participants in written reports and/or publications (especially if a single case is being studied in a well-defined field) and the restriction of access to recorded and stored data.

In this study ethical considerations are reflected in methods used to collect data and accumulated in Ethical Approval Form and Informed Consent Form used prior to the interviewing process. These forms cover the issues of confidentiality, data protection and security, voluntary participation, awareness of the research's purpose, reporting and issues related to further use of collected information and access to results (publications, presentations, availability of a PhD thesis in electronic format). Permission was sought to record the interviews to enable the researcher to analyse participants' contribution.

The main concern for public figures and companies' representatives is reputational harm. To address this problem the opportunity to review (see and comment on) the transcriptions of the interviews was offered.

Personal information is kept confidential to me as a researcher. Participants' identity is protected by concealing their names or other identifying information. For this purpose respondents were denoted by P(x) where x is a number. Generalisations were often used to conceal participants' identities, when a respondent was presented as a member of a group using a loose label (e.g. one of the consultants, one of the device developers). Nevertheless, the decision was made not to anonymise the case study itself (Wave Hub), which is rather unique, as the particular features of the project, its location and timing were important for the analysis. As a result, some actors (not individuals) involved in the project development can be identified (e.g. South West Regional Development Agency, PRIMaRE[22] or DECC[23]). The information regarding the project developers and some other organisations

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[22] The Peninsula Research Institute for Marine Renewable Energy
[23] The Department of Energy and Climate Change

involved was freely available online[24]. As such, it did not prove analytically useful to avoid naming these key actors.

Nevertheless, every effort was made to anonimise all individual contributions in any written outcome of the study or in any related publication. In case of publications ensuing from this research a name of a broad category of respondents will be used i.e. ‘company’, ‘public body’ etc.

The information provided by participants is kept confidential. All sensitive data was stored on a secure computer database and was not available to third parties (e.g. my academic supervisors) without due reason. Encryption software was used to secure the information in electronic format. Originals and copies of the recordings, as well as transcriptions of the recordings not specifically used in the final thesis, is to be destroyed at the end of the research project, anticipated to be no later than the end of the year 2013.

3.4. Case study

Case study analysis as one of the ways of doing social science research is often used to explore complex social phenomena (Yin, 2003). The focus on contemporary phenomenon and the type of research questions are the factors that determined the choice of this strategy: as the research topic involves the study of a technological object, a case study approach was seen as most suitable.

The case study deals with what can be called a ‘full variety of evidence’ – documents, artefacts, interviews, and observations, which supposes the reliance on a broader range of techniques than those used, for instance, in a history (historical study), adding two sources of evidence not usually included in the historian’s repertoire: direct observation of the events being studied and interviews of the persons involved in the events (Yin, 2003).

[24] Moreover, the key figures were explicitly named in the official documents and in online sources which were publicly available.

A single-case design was chosen in line with the theoretical framework to address the research questions. The operational definition of case study is provided by Yin (2003): 'a case study is an empirical enquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and its context are not clearly evident' (ibid., p.13). So the intention to cover contextual conditions which might be highly relevant for understanding the phenomenon in this study also explains the use of such method.

The renewable energy sector, and in particular marine energy, occurred as a possible field site as the result of deliberations about the development of new technologies that could have strong societal relevance and impact and draw a wide response. The articulation of preconceptions about innovation systems and renewable energy policy developments was also important for choosing this area. The study in the field of renewable energy was welcomed and encouraged by the University of Exeter Business School.

Interestingly, the association of my PhD project with renewable energy sector was perceived by outsiders and people within the industry as an advantage for my further professional development and as providing a certain flexibility choosing a career path.

Initially, this study was proposed under a general theme of organisational development of renewable energy. The aim of the research was to explore the organisational processes surrounding the development of a new renewable energy technology. Later, the theoretical vector of my research changed, as I realised that there was not enough sensitivity for analysis of socio-technical change looking at it solely from organisational perspective, and that STS offers more resources to understand the processes surrounding the development of new renewable energy technologies.

Besides, the phenomenon of interest may not become clear until some analysis has taken place and a number of attempts at theoretical interpretation of the data (Potter and Wetherell, 1987). As long as I was collecting empirical materials, the research themes became clearer and research questions became more focused and precise.

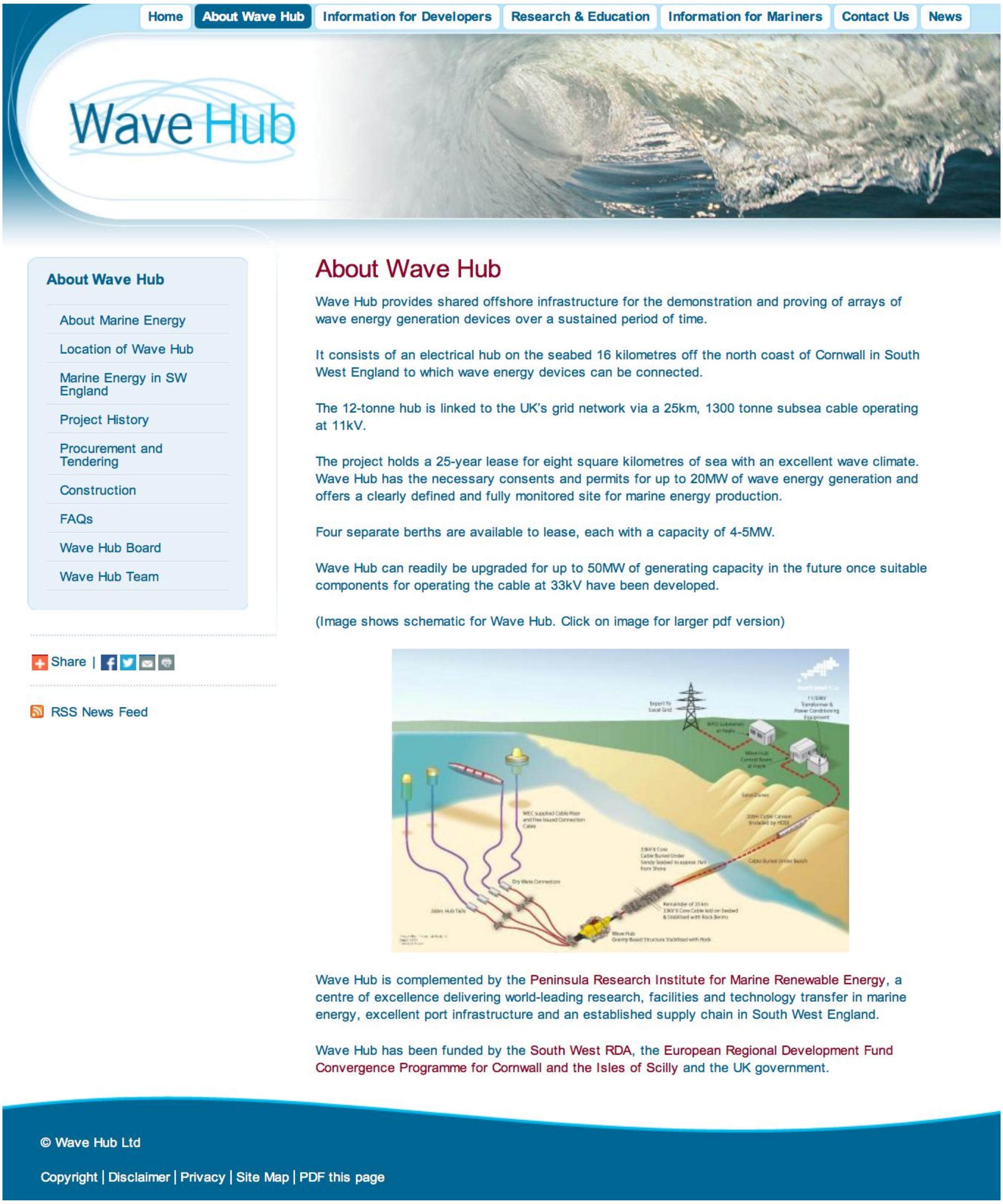
The selection of a field site can be characterised as a practical accomplishment emerging from my interactions with representatives of renewable energy sector, academics doing research in the field of energy policy and collection of preliminary data about the projects. These interactions revealed that marine energy is perceived as underdeveloped being at the demonstration phase, but having a big potential, especially tidal power. Although wave and tidal stream technologies were both seen as immature, tidal energy was perceived as more promising due to being less competitive and developing quicker, while wave energy was presented as more problematic mainly due to the diversity of the design options of wave energy converters and less number of wave energy sites around the world. Nevertheless, it was argued that there was the intention and the potential to build manufacturing industry in the UK for both, wave and tidal.

Thus, selecting my case study, I considered two potential research sites: the Severn Barrage, a tidal power scheme in the Severn estuary (from the English coast to the Welsh coast over the Severn tidal estuary)[25], and the Wave Hub project, which was proposed to meet the needs of wave energy industry (off the North coast of Cornwall). Eventually, I made a choice in favour of the Wave Hub case.

Wave Hub seemed to be preferable in terms of location, time scale and potential access. Exploring access opportunities, I found out that the University of Exeter was part of the Peninsula Research Institute for Marine Renewable Energy (PRIMaRE) affiliated with Wave Hub and partly sponsored by SWRDA.

[25] On 18 October 2010 the UK government announced that the project was being abandoned.

Fig. 1. Wave Hub (official website)[26]



[26] http://www.wavehub.co.uk/about/

This visual representation of the Wave Hub project, as well as the accompanying text, is to give the reader an idea of the official representation of the project in participants' discourse and to wake up the reader to the analytic need to consider images as an important part of construction of Wave Hub as a macro-actor. A set of visual representations will be used as part of my further arguments about credibility, design and expertise.

It was important that the Wave Hub case could give a possibility to study a technological project which was just about to be constructed and put into exploitation. The high expectations about the potential of the project and anticipated benefits for the local economy created certain projections to the future. It appeared that Wave Hub was a highly politicised project; it was contested and controversial throughout. From the beginning its technical functionality was thrown into question: there was an intriguing element in Wave Hub design – underwater transformers which were included in the initial design of the hub but later dismissed (I discuss this situation in my empirical chapters). Following technical issues, I then moved to public controversies surrounding Wave Hub. As Hilgartner (2000) noted, the study of extreme situations can be 'deeply revealing about mundane events'; in STS the analysis of controversies sheds light on how agreements are produced and displays the socio-technical networks that underlie the everyday operation of technology (Hilgartner, 2000, p.28-29). The failure in a technological project can also be seen as a methodological convenience as 'controversy surrounding failure tends to reveal processes that are more easily hidden in the case of successful projects and institutions' (Law and Callon, 2000, p.22). From this perspective, Wave Hub is an interesting case for analysis due to controversial routine, deliberations about its status and innovative nature, technological difficulties and unmet expectations.

Wave Hub is largely presented as a renewable energy project aimed at facilitating the development and deployment of wave energy technologies. The main narrative themes that one can find in the common description of Wave Hub are distance from the shore, technical capacity, purpose and functioning.[27]

[27] The latest official version describes the project 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. Wave Hub can readily be upgraded for up to 50MW of generating capacity in the future once suitable components for operating the cable at 33kV have been developed.' Source: About Wave Hub http://www.wavehub.co.uk/about/

The presentation of Wave Hub in the official discourse at the time of the preliminary design of this study (May-June 2010) also provided an idea of the project's scale and its political support (e.g. funding coming from SWRDA, UK government and EU), the objectives and anticipated physical qualities of the project, an idea of the needs and state of wave energy industry as reaching pre-commercial/commercial stage, as well as claims about its innovative nature ('first in the UK'). Containing scientific and managerial components, it was presenting Wave Hub as a controllable technological project without controversial aspects (which were later revealed in my analysis); it also was giving the sense of importance and a sound technological and scientific background.

My status in relation to Wave Hub was in some sense ambivalent: I was a part of neither the Wave Hub project nor other organisations involved in its development, but at the same time, in participants' perception, I was associated with Wave Hub representing the University of Exeter and having a member of PRIMaRE as one of my academic supervisors. Presenting the research project as a study under the academic supervision of one of the members of PRIMaRE was an important part of access negotiation and interview arrangements.

I was often asked by the participants about the outcome of my project ('a report') and its 'practical' value, which seemed to most of them as a worthwhile result of the research I was undertaking. Some of them expressed an interest in reading the final research paper or report[28].

The objectives of the study aligned with the managers' intention to make the project transparent and accountable as it was publicly funded. Publicity was an important component of the managerial strategy for the project. It not only helped to achieve representation of Wave Hub to specific audiences (i.e. academic community and interested practitioners), but also to sustain and enhance its reputation providing detailed explanations for the decisions made (especially those which probably did

[28] The participants, based on the explanation of the project provided, were assuming that my aim was to prepare a full detailed narrative – 'an honest account' of what really happened, and to discuss the lessons learned as a result of this project.

not look always reasonable in the eyes of other actors) and delays that took place during the development.

Nevertheless, I experienced some difficulties with access to everyday practices of the companies and organisations involved in the development of the Wave Hub project. A restriction on access to practical and organisational routines did not allow me to include an ethnographic component in data collection process. For instance, when interest was expressed to attend one of the PRIMaRE's meetings, a board member referred to the minutes of the meetings that, in his words, were publicly available. Thereby, my 'request' was politely dismissed.

3.5. Data collection

To underpin the qualitative approach of the research, I employed the following methods of data collection: documentary data analysis, including the assessment of existing published data; in-depth interviews (semi-structured and narrative); direct observation.

3.5.1. Semi-structured interviews

Interviews are widely used in research practice. As it is noted by Flick (2006), a goal of interviews in general is to reveal existing knowledge in a way that can be expressed in the form of answers and so become accessible to interpretation. Interviews never merely collect data; the information is always a joint product of a researcher and an informant, and the careful preparation work is essential.

The theoretical background of this approach is in the reconstruction of subjective viewpoints (ibid.). It is assumed that the interviewees have a complex stock of knowledge about the topic, and during the interviews the content of the subjective theory are reconstructed (ibid.). Different types of questions are used to reconstruct the interviewee's subjective theory about the issue under study. Open questions, hypotheses-directed questions can be asked which can help to make the interviewee's implicit knowledge more explicit. Asking confrontational questions serves the purpose of critical re-examining of the views and theories the interviewee has presented in the light of competing alternatives. It is suggested that the interview guide might include several alternative versions of such confrontational questions (ibid.).

The case study detailed in this research had to do with different groups of people and organisations (i.e. actors or stakeholders) represented by individual subjects (e.g. managers, government officers, company representatives). Participants represent both the public sector (including the UK government and local authorities) and the private sector (e.g. companies – device developers). These participants are usually people from senior management who are considered to be influential and well-informed about their organisations, as well as those who were directly involved in activities and operations related to the case study.

The initial choice of my respondents was prompted by my preconception about their identities and positions in relation to Wave Hub. The managers of Wave Hub, key staff members in companies and various organisations involved as well as local stakeholders representatives whose experience and knowledge could potentially contribute to the understanding of the emergence and development of the Wave Hub project were identified for interviewing. The online resources were widely used for this purpose (e.g. the websites of Wave Hub and PRIMaRE). Some names were put forward by the first few interviewees who also provided the researcher with contact details for several others.

The background knowledge about the participants and their activities was assembled prior to the interviewing process, generating so-called ‘interpretative contexts’ (Potter and Wetherell, 1987, p.164). The information about the respondents, their positions, as well as about the organisations, companies or public bodies they were affiliated with, helped to define an interviewing strategy, and at a later stage (analysis) gave me a fuller understanding of the organisation of the accounts. I also tried to understand ‘social representations’ (Moscovici, 1981) of the social groups to which participants belonged (e.g. academic researchers, consultants). It was suggested that such social representations underpin attributions or the casual explanations people provide for the events and are shared by the members of the group (ibid.).

These social representations were reflected in the models of the world constructed by the respondents and models of explanations.

Thus, at the first stage, publicly available information, including documents, was assessed to understand the roles played by various parties, or actors, in the Wave Hub project, their (professional) activities and/or their interests in development of renewable energy technologies in general. This was conducted prior to interviewing process, as well as for analysis of the interviews.

Most of the participants were contacted directly (by emails or approached at public meetings, i.e. conferences). In several cases participants were contacted via the assistance of personal contacts familiar with such persons, as well as through contacts provided by the academic supervisors. The standard invitations to take part in the research were sent to chosen subjects (individuals and organisations).[29] All participants were required to formally indicate their consent to participating in the research process by signing the Informed Consent Form (which was also available electronically in advance of meetings with the researcher). The Informed Consent Form highlighted the issues of confidentiality and voluntary participation, as well as describing the nature of the research project and asking permission to record the interviews. The participants were given the opportunity to withdraw from the research at any time prior to the publication of the research findings.

For identifying potential participants for further interviewing a so-called ‘snowballing technique’ was used, when the interviewees were asked to suggest names of someone who might be able to contribute to this research project.

The interviews were conducted with two groups of the participants: 1) those involved in the project under study (Wave Hub) – representatives of the local authorities (SWRDA), PRIMaRE (which included representatives of the University of Exeter and the University of Plymouth), funding agencies, public organisations, device

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[29] ‘Your name has been put forward because your organisation is/was involved in/associated with the Wave Hub project. If you are associated with a stakeholder group, you have been put forward as a person who interacts with participants and/or have certain expertise in the area.’ (*Informed Consent Form*, Introduction).

developers who had interest in Wave Hub, consultancies and contractors; 2) representatives of the industry – experts and consultants who were outsiders in relation to the case study and could discuss the perspectives for projects of this kind and renewable energy industry in general, the drivers and barriers towards its successful commercialisation, and governmental officers who were able to provide an insight and give an overview of the government perspective and degree of support for the project in particular and tendencies in renewable energy policy in general.

As it was mentioned earlier, twenty seven in-depth semi-structured interviews were conducted during the period from October 2010 to July 2011. University scientists and researchers were represented by the University of Exeter and the University of Plymouth and were mostly associated with PRIMaRE. This was the most diverse and representational group in terms of various subjects represented which included biology and biodiversity, energy policy, social impact and public perception of renewable energy, engineering (numerical modelling, electrical engineering, hydrodynamics and marine operations), resource assessment and modelling. Among twelve participants from academia three were also performing some administrative or managerial duties, and two were solely in management or project support. Two of the most vocal public organisations also participated in this study through their representatives (Natural England and Surfers Against Sewage). The wave energy industry was represented by companies – developers of wave energy converters (five participants) and consulting firms involved in developing renewable energy projects (two participants). The management of the Wave Hub project was represented by the South West Regional Development Agency (two participants) and by the engineering company responsible for the project management mainly at the construction phase of the project (two participants). The funding bodies, besides SWRDA, were also represented by Convergence Partnership Office (ERDF) and by the Department of Energy and Climate Change (Offshore Renewables Unit) (two participants).

Researchers would expect that the interviewed subjects' viewpoints are more likely to be expressed in an openly designed interview situation rather than in a standardised interview or questionnaire (Flick, 2006). In this research I used an 'in-depth interviewing' approach as the primary method of data collection. Conducting interviews (semi-structured and narrative) was characterised by introducing topical areas and by the purposive formulation of guiding questions.

The questions for semi-structured interviews were formulated around the issues arising from the case study and underpinned by concepts found in the literature. They were designed to capture respondent's perceptions and opinions about the Wave Hub project to date, their opinions on various aspects of the project development (including technical and organisational difficulties, delays and lessons learned), its innovative nature, credibility and legitimacy, production of knowledge around Wave Hub, the expectations and future perspectives, its ability to attract device developers, as well as relevant policy issues (e.g. financial and policy mechanisms for supporting wave energy in the UK). The participants were also asked a range of questions related to their professional activities including their professional development and work experience, responsibilities, relations to the Wave Hub project.

For the companies (e.g. device developers) the semi-structured interviews included the sections reflecting different aspects of personal and organisation's involvement into the project under study and its overall characteristics, an attitude towards the project, the management and technological profile, an access to finance, skills and collaboration within the sector, etc. Not all areas were relevant to all companies or organisations and could be either skipped or modified accordingly.

The interviews were conducted on a one-to-one basis, except for two interviews[30]. The interviews were conducted either face-to-face or, as in several cases, by telephone or via Skype, depending on availability, during the period from November 2010 to July 2011. Permission was sought to record interviews to enable the researcher to analyse the data. All interviews were recorded and transcribed.

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[30] In case with one interview two academics participated – one of them introduced me to another and participated in discussing the subject; in the second case one of the managers invited a colleague to clarify a few aspects of the issue discussed during the interview.

In addition to formal interviews, follow-up procedures were conducted in several cases (i.e. informal discussion). Such informal parts of the interviews provided additional data related to the study and an opportunity to explore some delicate themes in more detail.

The process of interpretations of interview data was made as clear as possible through the use of transcripts of interviews in the text of the dissertation. The selection of fragments of interviews aimed to make them as representative of the empirical materials (parts of the discourse) as possible (in light of particular research questions).

A distinctive feature of the interview data is that it is not necessarily consistent with regard to the themes I interviewed participants about (which were very diverse) and does not have a standard structure; the patterns of accounts were not always identifiable across interviews. The accounts largely depend on a position of particular respondents in a macro-actor configuration or in relation to it (i.e. affiliations, an access to the project under study, position in a professional network, etc.). As a result, different participants were able to through light on different aspects of the project development. Only several themes could be discussed with all of my participants. As my respondents represent different groups and 'communities of practice' (Wenger, 1998) and have different positions in relation to the project under study, a more individual approach for developing a line of inquiry in interviews allowed me to solicit a more personal opinion of interviewees. The situational nature of interviews also had to be taken into consideration. For example, the participants' accounts for 'mistakes' and 'pitfalls' (or 'failures') was a very sensitive topic, especially for those who were directly involved in decision-making process at different stages of the project development.

There was more general knowledge about Wave Hub (usually publicly available) and special expert knowledge (often technical) which the respondents tried to communicate to me as a social scientist. Attempts to explain Wave Hub to a 'lay' person resulted in some simplifications and additional explanations of specific terms (technical or scientific).

Practices of visualisation that I observed were presented mainly during interviewing process accompanying ‘expert’ discourse (drawings and sketches, handouts with slides, scientific images, photos and organisational diagrams).

The use of specific terminology (e.g. scientific ‘jargon’) and visual images and techniques in the interviews and follow-up data sharing were important elements of the discourse. I analysed it in relation to the politics of expertise as one of the research questions in this study (Chapter 7) and visualisation of the Wave Hub project (Chapter 6).

Although this research was not sponsored by PRIMaRE or the Wave Hub company, my affiliation with the University of Exeter played an important role for data collection and access to the field, and especially in approaching the contacts in the academic community. Despite a similar explanation provided to all participants about the research project (included in the informed consent form and introduction emails), the perception of this research and me as a researcher differed: from independent and distanced to deeply involved and sympathetic towards the project under study. This was particularly important when discussing sensitive issues, such as critical appraisal of different aspects of the project and its fulfilment, managerial practice, decision-making etc. When sharing their views, the respondents wanted to see me as a like-minded person.

Some of my participants identified me with PRIMaRE, assuming that I knew ‘a lot’ about the Wave Hub project prior to interviewing. Nevertheless, I could detect some hesitation about the degree of openness in conversation before expressing more radical opinions and criticism of other actors, e.g. ‘How critical can we be?’. During the interviews, the participants were constantly accomplishing a ‘boundary work’ deciding for themselves on the data and thoughts that they wanted and could share with a researcher. This indicates the delicate and sensitive nature of the topic to my participants. The clarifying questions were often asked about my research and its purpose, which in my perception prompted the respondents to decide on the degree of openness and other strategic issues.

My research raises questions as to the appropriateness of using certain data accounting for Wave Hub. In my conversations with the participants some, depending on the issues discussed, tried to avoid naming particular actors (e.g. companies who they were collaborating with), although the information about the companies and organisations involved was often available from other sources (including official documentation). Sometimes they were dropping a hint about those unnamed actors giving me a possibility to make my own conclusions and to identify them.

Some of my respondents demonstrated a willingness to be known as participants in this study, some preferred their names to be concealed; most of them preferred to check the interview transcripts prior to giving permission for using this type of personal data in the study.

3.5.2. Documentary data

Documentary information is likely to be relevant to every case study. This type of information may take many forms and should be the object of definite data collection plans (Yin, 2003). Documents are most often available in written textual format (in a printed form), but they can also have the form of an electronic file (e.g. various databases and online documents).

The status of things (or artefacts) as documents depends on their relevance and integration in the field of action (Flick, 2006). Because of their overall value, documents play an explicit role in any data collection in doing case study and can be seen as communicative devices produced, used, and reused for specific practical purposes (ibid.). Although giving quite specific and sometimes limited approach to experiences and processes, the analysis of documentary data can be seen as an addition to interviews and observations.

In discourse analysis documents are understood as 'complex cultural and psychological products, constructed in particular way to make things happen' (Potter and Wetherell, 1987). Documents, which are sometimes called 'harder data' (Gilbert and Mulkay, 1984), can include reports, studies, relevant publications, and often represent 'formal official discourse which is characterised not only by its source and possibility of access, but its specific ‘interpretative repertoire’ or ‘linguistic register’ (ibid.).

Online resources and electronic documents are often perceived as very useful resources for fieldwork. In this study electronic documents were an important element in situating my data collection activities performing as an extremely valuable source of data. As a rule, there was no exclusivity of access to online resources in relation to Wave Hub. The features of this category of documentary data had to be taken into account (the relative instability of texts – the date of access besides electronic address is required for references; differentiation between official and non-official sources is not always explicit, neither is authorship; availability is less problematic, and as such electronic sources of various kind might serve as a good starting point for introduction to the field or case study, as well as a rich source of data for further exploration and analysis).

Performing fieldwork and constituting the object of study in so-called ‘mediated settings’ (e.g. by means of electronic documents) has implication for the organisation of field work (Beaulieu, 2010, p.461). The ‘co-presence’ approach to doing fieldwork (or to shaping fieldwork) in opposition to physical ‘co-location’, as also suggested by Beaulieu, decentralises the notion of space (although not excluding physical space or face-to-face situations). Emphasising mediation as an important feature of social relations, it allows a researcher to consider new aspects of knowledge production that may not be strongly tied to a physically defined space (ibid.).

Although this concept was proposed for ethnography studies, I see it as relevant for defining the role of electronic resources in my research in particular (which are constitutive of my case study) and my approach to fieldwork in general.

Three main groups of documentary data were analysed in this research: 1) documents related to the case study – the Wave Hub project, as well as relevant information in mass media; 2) policy documents and relevant legislation; 3) organisations’ and companies’ documentation which was subject to accessibility.

The first group of documents mainly consists of official documentation publicly available on the project’s website. The key documents used in this study are Wave

Hub Technical Feasibility Study (2005), Wave Hub Summary Business Case (2005), Wave Hub Development and Design Phase (2006), Wave Hub Non-Technical Summary (2006); Review of Wave Hub Technical Studies: Impacts on inshore surfing beaches (2007); Wave Hub Environmental Statement (2006) with appendices A-N covering coastal processes, navigation risk, commercial and baseline fisheries, landscape and visual assessment, archaeological assessment, as well as surveys undertaken to inform the environmental impact assessment for the project (i.e. Habitat Survey, Offshore Bird Survey, Intertidal Bird Survey, Intertidal Study, Subtidal Benthic Survey, Environmental Baseline Survey[31]). The background studies available online also cover the strategic view of the marine energy development in the UK and the South West of England (e.g. Seapower South West – Supporting the development of a commercial wave and tidal current industry in the UK (2003)). The official documentation regarding consenting and safety zone were also publicly available online from www.wavehub.co.uk: Consent Letter (2007) (consent granted under Section 36 of the Electricity Act 1989 to the construction and operation of a wave power electricity generation station); a licence under Section 34 of the Coastal Protection Act 1949 (CPA) and licences under Part II of the Food and Environmental Protection Act (FEPA) 1985 for the installation of Wave Hub, its subsea cable and the stabilisation and protection of the cable by rock armouring; Safety Zone Consent Letter (2010).[32]

Press releases and articles in media sources helped to trace the evolution of the project, providing ‘factual’ information and coverage of the main events in regards to the project (e.g. approval of marine licence for the first Wave Hub deployment; Wave Hub winning national sustainability award), as well as performing as a source of the official discourse formed around Wave Hub.

The second group of documents is represented by policy documents and legislation in relation to renewable energy in general and wave energy in particular.

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[31] Wave Hub. *Environmental Impacts.* http://www.wavehub.co.uk/information-for-developers/environmental-impacts/

[32] Wave Hub. *Consenting and Safety Zone Information.* http://www.wavehub.co.uk/information-for-developers/consenting-and-safety-zone/

The government bodies, such as Department of Energy and Climate Change – DECC and Department of Trade and Industry – DTI (until 2007), as well as the UK Parliament (Energy and Climate Change Committee) and Carbon Trust are the main sources of policy documents in relation to renewable energy in the UK. The policy documents used and analysed in this study include *The UK Marine Policy Statement* (2011), *The Marine Energy Action Plan* (2010), *The UK Renewable Energy Strategy* (2009), *The UK Low Carbon Transition Plan: National Strategy for Climate and Energy* (2009). *The Renewables Obligation Order* (2009) and *The Energy Bill* (2012-2013 draft) are the key pieces of legislation relevant to this study. Reviews and reports prepared by advisory bodies and non-governmental organisations are also considered as relevant for this research project and are a rich source of data providing information about the state of the renewable energy industry and supporting the strategic vision of the future development of marine energy in the UK complementing official policy discourse (see, for example, Committee on Climate Change (2011) *Renewable Energy Review*; Renewable UK (2011) *Wave and Tidal Energy in the UK: State of the industry report*; Renewable UK (2010b) *Channelling the Energy: A Way Forward for the UK Wave & Tidal Industry Towards 2020*).[33]

The third group of documents includes organisations' and companies' documentation which provided information about their involvement in the development of Wave Hub, as well as general information about their profiles often available online (see, for example, Statement of research activity and capability of PRIMaRE, available form www.primare.org).

Two dimensions are important for documentary data: the authorship (personal and official, private and state documents), and the access to the documents (closed, restricted, open archival, open published) (Flick, 2006). These features can have an impact on availability of documentary data, especially in case of personal documents or documents with closed or restricted access. In my research most of the documentation related to the Wave Hub project that was analysed in the course of the study was freely available online[34]. Taking into consideration the massive corpus

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[33] For the full listing of policy documents, reports and relevant legislation see the list of references.
[34] Wave Hub. *Project History*. http://www.wavehub.co.uk/about/project-history/

of documents related to the case study (which also included documents in the field of renewable energy policy, wave energy etc.), I had to be selective about the documents I considered for analysis in this research.

The role of documentary data in this study was twofold: it helped to construct a coherent, overall view of the project (a 'possible history') filling what I perceived as 'gaps' in participants' recollection of events (e.g. historic recollection of dates, names), providing an 'official' version of the story; it was also a rich source of data for the analysis of the official discourse formed around the case study – Wave Hub.

My approach to analysing documentary data is based on the idea that documents are not a simple representation of facts and cannot be taken as literal recording of the events as they are produced for a particular purpose and form of use (Flick, 2006; Yin, 2003). Documents can be seen as a way of contextualising information and represent a specific version of realities (events or processes) constructed for specific purposes (Flick, 2006). It is suggested that 'rather than using them as 'information containers', they should be seen and analysed as *methodologically created communicative turns* in constructing versions of evens' (ibid., p.249).

In my analysis I am trying to suspend assumptions about the content of the documents (particularly, policy documents) bearing in mind the purpose and audience they were written for and their functions.

3.5.3. Observations

It has been suggested that if the phenomenon under study is not purely historical, some relevant behaviours or environmental conditions may be available for observation (Yin, 2003). It enables an understanding of both the context and process of behaviour (Remenyi et al, 1998). Such observations can serve as yet another source of evidence in a case study and be useful in providing additional information about the topic being studied, as it enables the researcher to find out how something factually works or occurs. As stated by Flick (2006), 'the theoretical background here is the analysis of the production of social reality from an external perspective' (p.219).

As the research questions include the description of the field under study and of the practices in it, direct observations were seen as useful element of the research strategy. The initial idea was to observe, beside the technological object itself, formal meetings in relation to Wave Hub, where the conflict of interests between actors (or stakeholders) and the differences in their positions could be uncovered and knowledge about relations in the studied field could be obtained. It is accepted that in case of studying a new technology observations of the technology at work could be invaluable aids for understanding the actual uses of the technology or potential problems being encountered (Yin, 2003).

Initially, field visits were perceived as desirable for studying Wave Hub as a technological object. Apparently, its physical properties and location made the direct observations of an object problematic to conduct. Besides, Wave Hub appeared partly as a virtual object construed by means of visualisation techniques and computer graphics; my participants were deliberating about the status of the project often using visual images of different kind (technical drawings, photographic images, sketches and drafts) and referring to the information about the project (textual and visual) on the Wave Hub website. From here my methodology assumes more attention to the electronic sources and various accounts of the participants involved rather than spending time at the Wave Hub site (physical location).

As suggested by Beaulieu (2010), 'being there' is no longer such a strong claim for an ethnographer, as access (for example, to a website) might be available to others, and co-presence relies more on coordination, flexibility and availability, rather than the ability to travel (p.459). Proposing not to worry about 'space' (whether actual or metaphorical), Beaulieu sees mediated settings (electronic resources, networks and infrastructure) as leading to re-articulation of the field and change of the researcher's role.

As such, the physical space of the project was not considered as a necessary and sufficient condition for constituting the macro-actor. Rather than organising travel and access to the construction site of Wave Hub itself, the challenge was to accumulate as many contacts as possible in relation to the project, arrange interviews with those who were identified as key actors, and organise the analysis of available documentary data (mostly available online). Online documents and news (press releases on Wave Hub website, Renewable UK newsletters, other media sources) became, in some sense, a means of ethnographic investigation.

The diversity and dispersion of the participants over a number of organisations and companies and the lack of opportunities to attend meetings (unlike traditional ethnographic study) was another obstacle for performing direct observations. Nevertheless, some less formal observations were made throughout field visits, on those occasions during which other evidence, such as that from interviews, was being collected. As such, only a few episodes could be directly observable, mostly the participants in their working environment (e.g. in a laboratory, at conferences), their interactions with each other and outsiders, and some elements of the equipment used by scientists.

3.6. Conclusion

In this chapter I have developed an approach to study a renewable energy project – Wave Hub. Starting with methodological positioning of my study, I introduced an actor-network theory as my main research strategy. Further, I explored the potential of ANT to accommodate a discursive approach in order to take into consideration variability of accounts and suggested a composite analytical framework for the purpose of this study. I made a choice not to streamline the narrative but rather to highlight possibilities, advantages and disadvantages of the research approaches I explored. This turned in my methodological approach became reflected in composition of my empirical chapters.

The political character of research is an important component of the research strategy, and it affected to some extent the choice of a research site for this PhD project. Renewable energy projects became a subject to social science analysis due to controversies mainly around their public perception. My interest in Wave Hub was to some extent provoked by its being controversial and highly politicised. I discussed the factors that determined the choice of my case study and its design.

I also discussed in detail the methods used in this study: semi-structured interviews, documentary data analysis, observations, and procedural aspects of data collection. The data collection process revealed some features of participants' accounts, such as, e.g., situational nature of interviews. The technical aspects, e.g. an access to the field, the choice of the participants, interview strategies, as well as ethical issues were discussed. I also paid attention to some practices I observed during the data collection (e.g. visualisation). The documentary data played an important role in this study. Helping to construct a 'possible history' of the project, the documents were also a source of the official discourse and representation playing a role in constructing a version of Wave Hub as a macro-actor. The presentation of Wave Hub largely as a virtual object and the physical properties of the field site determined my approach to direct observations as a method in traditional ethnography, which in large was substituted by data available in mediated settings (mostly in form of online documents) and direct contacts with the relevant actors.

Chapter 4. Emergence of a macro-actor: a possible history of Wave Hub

'Everything is uncertain. Everything is relational. And nothing is foundational.'
'...heterogeneity was the name of the game.'
Law and Callon (1988)

4.1. Introduction

In this chapter I begin to offer a sociological analysis of the Wave Hub project in Cornwall, UK based on the materials obtained from practitioners, academics, representatives of companies and public groups involved in or being related to this case study.

This story critically assesses the thesis about technological trajectories as the product of heterogeneous contingency (Bijker and Law, 1994), showing that there is nothing inevitable about the way they evolve.

Here I use the term 'a possible history' by analogy with the writing strategy used by Gilbert and Mulkay (1984). In their work on sociological analysis of scientists' discourse *'Opening Pandora's box'* the authors included a chapter called 'A possible history of the field' for the purpose of an introductory history choosing to ignore, or suppress, most of the variability in discourse. They use the metaphor 'Pandora's box' for the conflicting voices that spoke to them. Following this route, the authors emphasised that they were trying to tell a *version* of the history of research, recognising a degree of variability in the accounts, at the same time ignoring most of the variability to present a kind of a coherent outline of the history. According to Gilbert and Mulkay, this strategy allows the authors to provide the necessary background for an appreciation of the talk of the respondents (Gilbert and Mulkay, 1984).

My research revealed alternative versions of the history of Wave Hub due to variations in accounts regarding technical aspects, accounting for failures and lessons learned, and different judgements about the success of the project. Nevertheless, all these accounts allow reconstruction of the general historical narrative of the case. Quite often participants were not aware of certain details, did not witness or did not directly participate in the events for which they are providing accounts. In this situation they provide an 'account of accounts' which means adding their own interpretations and reflection on top of the information they obtained. The interviews with those who were directly involved in and participated in the project are the main orienter and the primary source of data for the narrative story.

Thus, the basis for this story is the differing but more or less consistent accounts of what 'really was happening' by different interviewees. For the analyst they all seem to be plausible and convincing, although vary in nuances and explanations provided for major events, failures and solutions. This strategy should not be seen as an attempt to force participants' discourse into one 'authoritative' account and losing sensitivity to interpretative variability among participants, as the variability in the accounts will be the subject of my investigation at a later stage.

In this thesis I will attempt to understand Wave Hub as an evolving socio-technical system and will draw on the concept of a macro-actor elaborated in actor-network theory (Callon and Latour, 1981). In the literature review I discussed this concept associated with Callon's approach (Callon, 1986), which describes a macro-actor associated with a single project. It was labelled as an 'entrepreneurial' version of ANT by Gherardi and Nicoloni (2005). The literature review also considered Callon's paper (1986) introducing the sociology of translation and discussed how this process (phenomenon) makes the construction of a macro-actor possible. By means of translation actor-networks grow, accumulating resources and comprising human and non-human agents, and at some point they impose themselves as 'macro-actors' (Gherardi and Nicoloni, 2005).

To understand the growth of a macro-actor I employ the concept of 'black boxes' (Callon and Latour, 1981). 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). It is suggested that an actor grows with the number of relations it can put in black boxes – the more elements it can place in black boxes (objects, forces, modes of thoughts) the broader the construction of a macro-actor (ibid.).

As it was discussed earlier, the difference between micro and macro-actors is 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). To examine a macro-actor, as suggested by Callon and Latour (1981), attention should be paid to the processes by which an actor creates lasting asymmetries. This means that the processes that lead to associations ('social' and 'technical') are not the main focus of concern, but 'the differences between what can be put in black boxes and what remain open for future negotiations' are relevant for an investigation (ibid.).

Bearing in mind this approach, I employ the concept of a macro-actor for analysis of Wave Hub. I examine the process of its creation and the associations that form the basis of this construction (not solely between humans) with the main focus on controversies and negotiation processes throughout the project evolution, 'the transformation of weak interactions into strong ones and vice versa' (ibid., p.300).

In this chapter I will reconstruct the history of the project starting with the development of the concept at the preliminary stage, moving through the feasibility stage and consenting process paying particular attention to the most controversial aspects.[35] Then the execution of the project including the tendering process and construction of the facility will be considered. At the end of this chapter, I will discuss the future of Wave Hub and its gradual materialisation.

In my analysis I will pay special attention to the contingencies that condition a project's success or failure by focusing on decisions that intertwine material aspects of the technological artefact, site where it is implemented, involvement of different groups, human and non-human actors, and social relations in which they are embedded. A version of Wave Hub history in the form of a thick narrative tracing the

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[35] Instead of deadlines and dates my participants referred to the main milestones (important events) in the historical development of the project; not always they could correlate them with particular date (a month or even a year).

main stages of project development is underpinned by translation of the story in ANT language with a special focus on problematisation, interessement and enrollment, as well as obligatory passage points.

4.2. Wave Hub: the birth of the idea

Renewable energy was an unknown terrain for the South West Regional Development Agency (SWRDA), as regards planning the development of a renewable energy project in the South-West of England. The vision of the future of the energy sector in the light of climate change, reflected in the UK government's energy policy, where 'green' energy will change the structure of the sector, was the main incentive for the UK Government to initiate renewable energy projects in the regions. The Government's initiative to provide partial funding for such regional projects, as well as the availability of financial support from the EU side, introduced an initial frame of problematisation by suggesting the development of a renewable energy development in the South-West. As it was explained by a few participants, in 2002 the central UK Government asked each of the regional development agencies what role it intended to take in assisting in development of renewable energy technologies, and each region had to consider what it wanted to do. Due to the belief in the 'goodness' of renewable energy and inevitability of 'greening' scenarios widely spread out within the society, the initiative was not contested and was taken as indisputable by SWRDA. Moreover, it stirred up enthusiasm as a very promising idea for economic development of the region[36].

At this stage SWRDA established itself as an indispensable element in the network – an 'obligatory passage point' (Callon, 1986) in the network of relationships they were building. SWRDA begins to translate the needs, the technical abilities and knowledge, the desires and aptitudes of a large number of actors.

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[36] Power relationship between RDA and the UK Government is not a subject for detailed investigation in this thesis. It is not a significant part of the participants' accounts.

The main question to answer for SWRDA was the nature of the project, e.g. type of renewable energy, they were going to pursue. According to the official information, Wave Hub, as a marine energy project at that time, was first conceived in 2003, when SWRDA considered which renewable energy technologies would present the best opportunities for economic growth in South West England.[37] When SWRDA made the decision to develop a marine energy project, advice was taken from an industry panel which brought together representatives of the industry, utility companies and academics, who reinforced the emerging framework of problematisation by suggesting the idea of Wave Hub. The consensus was achieved that such factors as an excellent wave climate and the available capacity in the electrical grid near the coast made the concept of a consented grid connected site for the demonstration of wave energy devices the most attractive proposition as part of a wider UK offer to the marine renewables industry.[38] The existing infrastructure to support marine energy industry such as ports and docks, a ship building industry, good transport links and especially an electrical grid were taken into account. Since no one contradicted the concept put forward by the panel, this decision was held as incontestable.

After consultations with a panel of industry experts[39] and preliminary feasibility study[40] SWRDA placed the evolution of the wave energy industry as a whole in a black box, henceforth assuming a need for a new array testing facility, and this kind of project would be feasible to execute. The black box was closed and sealed up; the decision about the aim and the nature of the project was made and never revised.

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[37] Wave Hub. *Project History*. http://www.wavehub.co.uk/about/project-history/
[38] Ibid.
[39] SWRDA/RegenSW, 2003. *Seapower South West – Supporting the development of a commercial wave and tidal current industry in the UK*. Appendix B: Members of the SW Expert Panel on Seapower. http://www.wavehub.co.uk/wp-content/uploads/2011/06/2003-October-Seapower-South-West-Report.pdf
[40] SWRDA/RegenSW, 2003. *Seapower South West – Supporting the development of a commercial wave and tidal current industry in the UK*. http://www.wavehub.co.uk/wp-content/uploads/2011/06/2003-October-Seapower-South-West-Report.pdf
Metoc plc, 2004. *Seapower SW Review – Resources, Constraints and Development Scenarios for Wave and Tidal Stream Power in the South West of England*. http://www.wavehub.co.uk/wp-content/uploads/2011/06/2004-January-Seapower-South-West-Review.pdf

Right from the beginning, this development was seen as complimentary to NaREC[41] and EMEC[42], as the third element of infrastructure for testing and demonstration of wave energy converters 'just before their commercialisation'. (P1) At the same time, the project was seen as a core element which would determine an industrial revival for the South-West of England, as an industrial restructuring project that would provide local benefits.

The implementation of the idea raised a problem for project developers. What would be the precise configuration of the project? What do developers of WECs need? How to deliver it? Who would be involved and who would be able to lead and organise the project?

The first task for SWRDA was to ally companies who would be the potential users and whose needs SWRDA was intended to meet (translate) through this project. Prior to detailed elaboration of the idea, the interest and preferences of potential customers were investigated. The attempt to identify the needs of potential clients was made through surveys including questionnaires which were sent to numerous ('twelve-fifteen') device developers[43]. They displayed different degrees of interest in such a facility and had a chance to comment on the proposal. (P2) By doing this survey, the managers of the project could claim 'the right to speak authoritatively on behalf of users' (Grint and Woolgar, 1997, p.74), as device developers in this case can be considered as users. As a result of this negotiation process, three companies who seemed 'sufficiently advanced' for SWRDA were chosen at that time, the fourth was added subsequently (P1).

Having defined the evolution of the social world, SWRDA determined the evolution of techniques. Techniques, or 'technicalities' (technical side of the implementation of the idea) (Jolivet and Heiskanen, 2010) were distinguished from the 'socialities' (social world) (ibid.).

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[41] National Renewable Energy Centre
[42] European Marine Energy Centre
[43] The responses were summarised in Final Report of Wave Hub Technical Feasibility Study (January 2005) covering the questions of developers requirements, readiness of their technologies, anticipated timeline for the first commercial demonstration/deployment etc. According to this report, from the 29 initial questionnaires sent out, detailed replies were received from 13 developers.

The possible options elaborated centred on bringing the idea of a wave energy testing site into existence where multiple renewable energy technology companies would be able to take advantage of shared, expensive infrastructure provided for them by SWRDA to test arrays of wave energy devices. The general conclusion was favourable: a new offshore deployment site would allow testing devices in arrays at full scale for a number of years with a permit for the site, an electrical cable and a grid connection in place.

Thus, the social and technical premises were laid down and the scenarios elaborated. It was planned to finish the construction of the project in 2008. SWRDA foresaw a high demand for the testing site for wave energy devices.

4.3. Feasibility stage and consenting process

Once a framework of problematisation was put in place, i.e. the general concept approved, potential allies, who could perform the successful translation of the idea, became the focus of attention. So an interessement process continued, through which the identity of the identified actors was being imposed and stabilised. The actors identified and the relationship envisaged need to be tested and go through the set of trials of strength to prove the solidity of problematisation (Callon, 1986). It is suggested, that each potential actor can accept to be integrated in the proposed plan or refuse the transaction by defining its interests and identity in another way (ibid.).

At a certain stage, it was necessary to identify the actor who could act as a host for Wave Hub itself, an organisation who would actually run the project, as at that moment the RDA itself could not perform this role according to the regulation (P3). After negotiations with a few companies – potential owners and operators, the RDA turned to two universities who, as they believed, could join forces to perform this role. In 2005 the RDA came up with a proposal for the University of Exeter and the University of Plymouth to run Wave Hub as a commercial entity. But the universities were pending the transaction (for about six months); interessement was not successful and enrolment in this form was not achieved – the universities refused the transaction, although not refusing to being integrated into the project. In this situation, they defined their identity, goals and orientation in a different manner in relation to the project – as research institutions (initially called 'Wave Rim'). As a result, the idea of a research entity linked to Wave Hub – the PRIMaRE[44] institute was brought forward and successfully implemented.[45] Moreover, the enrolment of this actor was transformed into active support. In the meanwhile, the rules (Treasury guidelines) were changed, and SWRDA was able to play this role itself.

Explaining the involvement of research institutions (i.e. universities) and the desire of the management team to get them on board, the participants pointed to the expertise that these Universities accumulate and their ability to produce new knowledge, needed by the industry, through their involvement. As a few participants agreed, beyond the question of raising finance, there was 'a lot' to learn about different aspect of mooring of devices out of the sea, wave climate, the installation and connection of devices, the maintenance, monitoring environmental impacts and potential social and economic impacts. It determined the decision to work with the University of Exeter and the University of Plymouth, and to launch the PRIMaRE research centre. (P1)

SWRDA established itself as an obligatory passage point for other actors aiming to enter the network, but also needed allies in order to pursue a proposed project. The task for SWRDA was to find another actor capable of acting as an 'engine', turning the existing problematisation into a real project. So the obvious way to do it was to exploit a previous translation and hire a consultancy they previously worked with and who had already proved to be reliable, as it would require less effort. The consultancy hired had in the past been able to constitute a dependable and aligned networks, which 'in business terms means being able to deliver the product/service promised' (Gherardi and Nicolini, 2005, p.293).

Therefore, in 2003 the contract was signed with Halcrow[46], a multidisciplinary consultancy with expertise in all the different fields including renewable energy (P2).

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[44] The Peninsula Research Institute for Marine Renewable Energy http://www.primare.org/
[45] A contract for two universities started in June 2007.
[46] Halcrow Group Ltd delivers planning, design and management services for developing infrastructure and buildings worldwide. They were working as consultant engineers to South West

It cemented the enrolment of the consultancy defining its role and tasks. The consultants started pursuing problematisation of SWRDA's needs, which was implemented in the detailed elaboration of the concept, preliminary studies and consenting process.

At this stage SWRDA relied heavily on expert advice, involving, beside Halcrow, other organisations each bringing different level of expertise and forming together a multidisciplinary team. For example, the economic appraisal was done by Garrad Hassan, a large renewable energy consultancy.[47] As was admitted by some participants, they also understood that they would need assistance from specialists in the marine industry. One of the major offshore contractors was engaged for the purpose of assisting with the concept designs. (P2)

In 2005 the main studies were conducted - Technical Feasibility Study, Legal report, and Business case, which represent what can be called a 'sociotechnical scenario' (Law and Callon, 1988). According to these documents, 'a network of design elements' for Wave Hub was in place leaving little doubt about feasibility of the project, although the scenario was based on the 'design for an ideal world' (ibid.). The 'social theory' of SWRDA was incorporated in the proposed technological project – its design and specifications was partly informed by social considerations and reflected SWRDA's notions about relevant actors, their capabilities, intentions and roles, as well as a theory about how wave energy industry would develop and what it could be in the nearest future. This 'putative sociotechnical network' (Law and Callon, 1988, p.287) elaborated in Technical Feasibility Study, included not only social actors but also technical elements and natural phenomena.

It was accepted that the engineering design concept for Wave Hub was thoroughly researched in the Technical Feasibility Study. The choice of the concept design – a wet hub utilising underwater transformer technology – was informed by several considerations, i.e. safety and reliability of an installation, minimal visual impact, relatively low capital cost. The underwater system was the clear leader for the final

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Regional Development Agency on the Wave Hub project. http://www.halcrow.com/Our-projects/Project-details/Wave-Hub-England/
[47] GL Garrad Hassan http://www.gl-garradhassan.com/en/index.php

choice, and a design freeze has now taken place to allow preparation of suitable tender information.'[48] Another black box was closed as it seemed to the managers.

The questions about design (as well as about construction of a technological artefact in general) are both technical and social, and the answers to these questions imply decisions about the definition and distributions of roles between the object and its environment (Callon, 1991). The elements construed as 'technical' and 'social' (and even a natural phenomenon) are involved in a struggle through which a macro-actor is structured: the state of technologies, the social groups involved, the policy in the field, the dimensions of the actors and the ideas they pursue.

In the original design of Wave Hub it was planned that there would be a need for power connection units (PCU) on the seabed to increase the voltage, which would be comprised of electrical transformers built inside a protective shell framework. But this initial idea has not been implemented in practice. In ANT language, the endeavour to align one of the key elements – transformers – revealed the risks involved, the transformers refused to be mobilised and aligned as SWRDA and the consultancy envisaged, and this was a significant change in the concept of Wave Hub. Although these transformers were only in a form of an idea and a drawing depicting an artist's impression, they were 'real' for actors at a certain stage. It was not possible to make a distinction between a reality and something dreamed up by engineers, all actors behaved as if the transformers were an essential integral part of the artefact. Only through building new associations and bringing new actors in (a new management company), this 'reality' was destroyed at the execute phase.

Besides the conceptual design of a technology, a suitable location for Wave Hub was another important aspect of the project design. The principle factors that determined the boundaries of the proximate area were a suitable connection to the electricity grid, which was possible through the existing power station in Hayle, North Cornwall; the preferable deployment area for WECs which was characterised by the best energy resources available (wave climate and required water depth); and

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[48] Halcrow Group Ltd/SWRDA, 2006. *Wave Hub Development and Design Phase. Final design report*. http://www.wavehub.co.uk/wp-content/uploads/2011/06/Wave-Hub-Final-Design-Report.pdf

distance from the shore. Other factors that had to be taken into account as potential risks were fishing and navigation activities in the area of the proposed location of Wave Hub, the military exercise area, the wrecks on the seabed and the seabed conditions (which were especially important for the cable route).

The site for Wave Hub became a major point of criticism and negotiation in the course of the controversy. For projects like Wave Hub the geo-history[49] of the area and the various technologies employed are of particular interest in defining who was involved, what interests were implicated and how these interests were negotiated (Jolivet and Heiskanen, 2010). The process of choosing the location for Wave Hub was closely interwoven with building a consensus with other users of the sea. At this stage new actors were brought in whose interests might be affected by the project, and those who must grant various consents[50]. Among them there were the fisheries organisations, research organisations, environmental groups (including Surfers Against Sewage), local businessmen, archaeologists, the statutory bodies and NGOs, etc. The negotiation process illustrates how the management team constructed the consensus achieved and how in turn the very idea of consensus was constructed.

According to ANT, the process of enrolment is always a trial of strength for the actors that are going through this process with controversy. It can reveal the complexity of the networks that stand behind each associated entity putting the entity under suspicion (Callon 1989). The consenting process in the case of Wave Hub was the biggest trial of strength for the actor-network. The Wave Hub location suggested by consultants was based, in ANT terms, on a programme of negotiations – hypotheses and interpretations of the seabed conditions, shipping routes, the depth needed for devices, the areas reserved for fishing, the wrecks on the seabed, etc. As this process was extremely controversial, certain aspects of it need special attention and will be discussed in more detail in the following section.

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[49] Geo-history is taken to mean the geographical history of the area (geographical, geological and historical dimensions of a locale).
[50] Appendix B 'Consultee list' in Halcrow Group Ltd/SWRDA, 2005. *Wave Hub Technical Feasibility Study. Final Report*. http://www.wavehub.co.uk/wp-content/uploads/2011/06/2005-January-Wave-Hub-Technical-Feasibility-Study-Final-Report.pdf

4.4. Analysing controversies

Studying controversies provides relevant insights for understanding various practices, an insight into how consensus and certitude were achieved; solving controversies is a part of creating a technological artefact. A controversy can be viewed as an encounter between different people and interests, but it can also be viewed as an encounter between a new technology and a new site, as well as their associated socio- technical networks. A number of studies in STS based on detailed case studies emphasised the importance of controversies in socio-technical development, highlighting complexity of scientific and technological innovations (e.g. Pinch & Bijker, 1989; Law and Callon, 2000; Mackenzie, 1989; Latour, 1996; Latour, 1987, etc.).

Controversy analysis is a significant part of a discourse in actor-network theory. In ANT controversies can be considered as alternative efforts of competing networks of actors to 'frame' the reality and enrol others (Callon, 1986; Jolivet and Heiskanen, 2010). One of the founders of ANT Bruno Latour developed this theme within the sociology of associations, for example, in his book *'Reassembling the social: An introduction to* actor-network-theory' (2005). He also developed cartography of controversies as a didactic version of ANT for investigation of contemporary socio-technical debate (Venturini, 2009).

To examine the problem of controversies the concept of relevant social groups (Pinch & Bijker 1989) is very useful, as it is necessary to define the relevant social groups for whom the project could constitute a problem. But the question of representation for such groups can become disputable for some reason. As it appeared, there was no unity among fishermen, surfers, locals, device developers etc. At the planning stage, the project managers could not envisage the networks complexity of the social groups they would have to deal with. Trying to ally various actors (social groups), the managers attempted to address them as united groups defining their identities and needs as they saw them. It seemed to be a reasonable step, as it was impossible to cope in practice with endless networks ramification. Since these groups refused to demonstrate the unity, and initial punctualisation was very precarious degenerating at some point into failing networks, additional efforts had to be made to align them and achieve a punctualisation effect.

Examining the problems each group had with respect to Wave Hub reveals the conflicting positions adopted by some actors who developed their own interpretations of the project. Although the public perception of the project was good in general, the management team had to address concerns of numerous actors, more or less powerful, who could and did have a significant impact on the trajectory of the project. At this point, the project managers' view collided with a competing attempt to preserve the site for fishing, surfing, etc.

The material gathered here suggests that a number of Governmental and public bodies and other powerful organisations were involved in this process. The potentially adverse impacts of Wave Hub on safety of navigation, fishing activities, surfing and tourism, as well as concerns regarding the appropriateness of a wave powered generation project, its location and energy cost, led to a number of objections that had to be taken into account by the regulator (Department for Business Enterprise and Regulatory Reform).[51]

According to the respondents, the biggest concerns that they had arose from the navigation consultees and regulator. There was the whole route of consenting on this issue. The Governmental body responsible for energy was the main consenting authority under the Electricity Act. The Marine and Coastguard Agency (MCA) was the regulator for navigation issues, and its view was crucial on whether the scheme should be approved. Two other organisations – Trinity House (the general lighthouse authority) and the UK Chamber of Shipping – were particularly important as they perform as consultees providing advice to MCA, and they had their own view on the project. These organisations were described by participants as powerful and not interested in renewable energy at all but 'making sure the captains of boats just keep going up and down the Bristol channel without even worrying about anything' (P2). They raised concerns about the position and visibility of the site and possible

[51] Department for Business, Enterprise and Regulatory Reform (DBERR) was a UK government department created in June 2007 on the disbanding of the Department of Trade and Industry , and disbanded in June 2009 on the creation of the Department of Business, Innovation and Skills.

impacts of Wave Hub development on navigational safety. Even though the opinion of these organisations was not mandatory for MCA, it was felt by the managers that the person at DBERR who was responsible for the consent under the Electricity Act might choose not to go against the advice of his consultees. This created a ‘nervous moment’ for the Wave Hub team. Consequently, a lot of negotiations followed, new surveys and data were produced, reports were written proving that navigation risk was acceptable. As a result, the Wave Hub location was moved to reduce the impact on shipping routes, although their concerns were never fully addressed, and the Chamber of Shipping has never become an ally.

Another group of powerful actors were organisations with environmental concerns. The respondents pointed to the Joint Nature Conservation Committee – the public body that advises the UK Government and devolved administrations on nature conservation issues, and Natural England – the Government’s adviser on the natural environment. And although these bodies had deep concerns about the environmental impact of Wave Hub and activities surrounding the project, they were prepared to accept the experts’ conclusions, and their consent was obtained without much discussion. As a result, they were enrolled at this stage without serious resistance. The likely environmental impacts were also judged as acceptable by the regulator.[52] Callon and Latour (1981) suggest, a macro-actor does not have to negotiate everything with equal intensity; rather it can go on and count on a force while negotiating for another. That is how it happened in the case of environmental concerns and potential impact on the environment. It is noteworthy that the biologists suggested that it was impossible to predict the potential impact as it requires a number of years of monitoring – both prior and after installation of devices. (P7, P8)

Fishing industry was another source of serious concern. While the sector is getting smaller, it still has a lot of political power because of the historical importance. Suddenly, the idea of ‘Britishness’ became important, which participants highlighted in relation to this social group and its role in the society: ‘It’s difficult negotiating with fishermen and that’s been found in numerous jurisdictions because they are a

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[52] Section 36 Consent. Wave Hub. *Consenting and Safety Zone Information*. http://www.wavehub.co.uk/information-for-developers/consenting-and-safety-zone/

powerful group of people, they are very close to the hearts of the British people particularly in the coastal areas. People care about what happens to fishermen because it was an industry which was the basis for employment for hundreds, for thousands of years, and that's quite important.' (P2)

Providing an explanation for long-lasting negotiations with fishermen and accounting for complexity of the process, one of the interviewees said: 'And a lot of the fishermen despite telling us that these were their main trawl routes, suddenly changed their minds when we actually presented them the site. And you get this because on one day you hold a public exhibition one group of fishermen are coming and draw lines on plans quite fantastic, and then they all retire or sold their company to somebody else and then they come in: 'Oh, opportunity to make a fuss and perhaps get some money!'.

The project officers envisaged that there would be less fishermen affected if they chose mostly rocky seabed for the cable route and Wave Hub location. That was due to the impossibility for using trawling nets there, and only the crab and lobster pot fishermen use those areas. Four by two kilometre grid of berths for Wave Hub sits right over one of those fishing grounds. This means that a small group of fishermen were affected in quite a large way as they had to be displaced. This made them object to the scheme. To resolve this controversy, the compensation scheme was introduced where, besides addressing the individuals affected the most, the measures providing benefits for the whole local industry were offered in the form of compensation (such as improving storage facilities, improving safety measures, etc.). Granting consent, the regulatory authorities (DBERR) decided that there was no justification for calling a public inquiry into this aspect of the proposed development.[53]

These lasting controversies can be explained as the fishing community (that was taken as a black box since they first expressed their opinion) is also a heterogeneous network that changes its configuration (new people come, some

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[53] Section 36 Consent. Wave Hub. *Consenting and Safety Zone Information.* http://www.wavehub.co.uk/information-for-developers/consenting-and-safety-zone/

leave), thus a new vision of the problem and new claims can occur. It is also a very powerful network. In this situation relevant legislation (compliance with legal requirements), political decisions, signed agreements which help to shape the 'final' solution (which otherwise may not be final as the process can be endless) and actually to fix the networks, work as a stopper, allowing to close the problem, and define the boundaries. The solution to provide compensation to the network (local fishery industry) addressing its needs as a whole indicates the intention of the managers to deal with this network as one actor, enforcing a punctualisation effect to stop the endless complexity. So the fishing industry was reduced to the fishermen-that-want-to-preserve-their-fishing-site.

As discussed in the literature review, the idea of punctualisation is one of the basic concepts in actor-network theory. It is based on the notion of simplification which is used to account for the reduction of an infinitely complex world (Callon, 1989). In other words, punctualisation is seen as a precarious simplificatory effect that accomplishes the idea of abstraction, assuming that all phenomena are the effect or the 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 (Law, 1992). Thus a punctualisation effect is seen as an important feature of the networks. John Law (1992) suggested that punctualisation is a process or an effect, rather than something that can be achieved once and for all. It goes in line with his statement that 'social structure is not a noun but a verb' (ibid.).

An interesting situation occurred during the negotiations with the surfing community as it involved not only surfers, scientists and managers, but also waves as a non-human yet extremely powerful actor. The surfing community was a powerful social group whose voice had to be heard, as surfing is very popular in the South-West. An active representative of the community participated in public meeting from the early stage of the project ensuring that recreational water users had a voice and any possible impact was investigated thoroughly and independently. The surfing community, whose interests had to be addressed (or at least presented as such), was not united since the beginning of the negotiation process. The process of interessement of surfers revealed the complicated structure of this network with tensions between different groups and disagreements within the community. There were two main surfing groups, one of which – Surfers Against Sewage (SAS) was in favour of Wave Hub as they claimed that they could envisage the overall benefits to a society. This group was not deliberately negative, and their members were characterised as 'very sensitive environmentally' (P1). They present themselves as fully supportive of offshore renewable industry and did not actually object to the Wave Hub project. (P6) Another pressure group was formed among surfers against Wave Hub, although less popular, they were asking 'difficult' questions about possible impacts in the form of the wave height being reduced. (P2)

The main thrust of the protests among surfers was the potential for offshore WECs to negatively impact on shoreline wave height. Since wave height is a reflection of the energy carried by a wave, then it can be expected that drawing energy from the waves would have an impact. Controversy followed from debate as to the possible scale of the impact. This process involved negotiations not only with humans (surfers), but also with non-humans (waves) in the form of studies regarding possible height reduction and their coverage in media, which can be seen as interessement devices.

There was a series of attempts to calculate possible impact of Wave Hub on wave height. The participants that commented on this episode were not scientists themselves, but they were bringing a different kind of calculation as evidence and referring to the documents and studies. The first study prepared by Halcrow (Environmental Impact Assessment) in collaboration with SAS reflected the worst possible scenario and suggested a maximum possible figure of a 13% reduction in wave height (based on effectively ideal wave conditions for surfing). Participants suggest that the likelihood of that 13% was extremely low, and it has been noted elsewhere that the conditions occur less that 1% of the time, but in the EIA process they had to look at the very worst case scenario. At this stage the media became involved and 'did a good job creating a storm in a teacup', with coverage of the 13% figure appearing in the UK national press and as far afield as Australia. (P6) The next study prepared by experts from the University of Exeter concluded that the possible impact more likely to be in the order of 1.5%. It was published in the Ocean Engineering Journal and peer-reviewed, based on 'real sea data', so this study was seen as independent and the most important for SAS. (P6) Then finally, following the continued highly vocal objections of the British Surfing Association, an independent scientist from New Zealand, Kerry Black was brought in as a consultant to investigate the impact of wave energy converters on wave climate at the shore of the north Cornish coast. At the end, the experts agreed on what the likely impact might be, and it was judged as minimal. Discussion of the studies showed that surfers were prepared to accept the studies' conclusions and judge them to be convincing. So the perceived impact on the surfing industry was announced as acceptable by both experts and surfers.

A few participants who were directly involved in the consenting process describe the serious difficulties they experienced and challenges they faced, although suggesting the general public perception of the proposed scheme was positive. The local population was offered what was believed to be a beneficial 'socio-economic transformation of the area'. The local authorities for Cornwall, Cornwall County Council, did not object to the Wave Hub project nor raised possible impact on tourism as a concern.[54]

What appears as a common theme in the interviews are difficulties with legal framework within which the project was being developed. As one of the examples, the participants pointed to the situation around granting consent: there was sufficient UK legislation to grant consent to build the project, but there was no legislation in place to close the area to shipping, which obviously was not safe. Later, the subsequent changes were made to enable that to happen. (P1) Explaining the way planning decisions are made by the regulatory authorities like DBERR (from the outsider's point of view), the participants suggest that a conclusion about the relevance and justification of the objections (public or regulator's) is often based on a compromise and is made 'for purposes of the greater public good'. (P2) This suggestion is supported by the relevant documentation where the proposed development was approved and necessary consent was granted by the official authorities (DBERR). As it was declared, the deliberations about possible adverse impacts and related objections could not justify a refusal of development approval,

[54] Section 36 Consent. Wave Hub. *Consenting and Safety Zone Information.* http://www.wavehub.co.uk/information-for-developers/consenting-and-safety-zone/

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'.[55] Renewable energy projects are recognised as having an important role in helping the UK meet its renewable targets, although may not always convey particular local benefits; nevertheless, the benefits to society and the economy as a whole of more diverse supplies of energy justify this type of development.[56] Responding to the issue of levels of energy consumption as against generation, the regulator saw it inappropriate to make the project subject to a public inquiry on this ground because such projects are seen as important 'for the purpose of learning lessons that can be applied to future, larger scale projects'.[57]

After several attempts, all disputes were resolved, or at least presented as such; the work done by the management team was considered as sufficient. The application was accepted by the authorities responsible for consent and the necessary permissions for the project were granted. Using ANT language, the actors were interested and aligned in order to form a sufficiently coherent social-technical system. At this particular stage and for this particular translation (consenting process) SWRDA became a spokesman for all assembled actors, who since became silent and mobilised. The consents granted by the authorities closed another black box – a long and complicated consenting process. It cemented the enrolment of governmental bodies and other organisations and public groups involved in this process.

4.5. Executing the project: construction of the facility

Moving to the next phase of the project development – construction of the facility, SWRDA faced new challenges. It appeared that the response to the initial tender prepared by SWRDA was significantly more expensive than expected, 'in so far as it

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[55] Section 36 Consent. Wave Hub. *Consenting and Safety Zone Information.* http://www.wavehub.co.uk/information-for-developers/consenting-and-safety-zone/
[56] Ibid.
[57] Ibid.

almost put a stop to the whole thing'. (P3) Besides that, a few participants agreed that there was a certain degree of dissatisfaction about the work done by the consultancy. And although at certain stage the role of Halcrow was dismissed, the process of interessement did not fail, as the amount of work done by this consultancy, its input was significant, especially through the consenting process. Nevertheless, it was necessary to enrol another actor who would be capable of accomplishing the translation of the concept into reality – a material thing or a built facility. At this time SWRDA was eager to sign a contract with someone with a proven track record in the field of offshore engineering.

As a consequence, in late 2008 SWRDA signed a contract with an engineering company, JP Kenny[58] to take the project further (to execute the project as managing contractors) and at first to help SWRDA with the tendering process. The scope of the work for JP Kenny involved the development, design and installation of the entire electrical infrastructure, from the point of connection to the Western Power Distribution network through to the hub tails located some 25km offshore.

JP Kenny had considerable experience in project management with distinctive competence in pipeline and subsea engineering, and was seen as capable of assembling all the pieces together to actually execute the project. As the relations between SWRDA and the managing company were formed on a contractual basis, JP Kenny had significant degree of freedom acting on the RDA's behalf, and within the delegated authority made important decisions for the project's success which were formally approved by SWRDA. In fact, at this stage for new actors this company played the role of an obligatory passage point on behalf of SWRDA. However, JP Kenny's position as an obligatory passage point depended on its ability to continue the construction of the actor-network predicated on its problematisation, to mobilise other actors including the technological artefact (subsea construction) itself.

Their reputation as experts in offshore construction and installation work was not the only factor that led to this involvement. As a representative of the company

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[58] Specialists in pipelines and subsea systems http://www.jpkenny.com/Pages/Default.aspx

explained, ‘I think we do a good sales job on them at some set.. Our Managing Director knew some people there.. through business development and networking.. I think the opportunity to support them and we get them a proposal which they quite liked.’ (P4) Other respondents admit that their professional reputation and experience played a decisive role, although Wave Hub was the first wave energy project for this company. Having a proven track record in the oil and gas field, this new managing company saw Wave Hub as similar to other projects they had done before. As a result, previously built relations were exploited; the same players were involved as subcontractors from the construction and supply view point. According to one of the interviewees, it came as a surprise for project managers that there seems to be a reluctance for the renewable energy sector to build on the experience in offshore oil and gas, which could possibly be explained by ‘the tighter squeeze on the finance’.

This management company represented a certain ‘community of practice’ in oil and gas sector, which has standard arrangements and conventions of use about materials, standards, goods etc. (Star, 1991). The knowledge and skills possessed by the industry were seen as a flexible resource that could be integrated into new sociotechnical arrangements (i.e. renewable energy). The prevailing logic of a well-established network – offshore oil and gas sector became dominant for the next stage of project development and defined the final design of the infrastructure. This engineering company applied the principle they always follow in their work in the offshore environment – ‘Keep It Simple Stupid’ (KISS): ‘...certainly one thing we have quite carefully concentrated on is trying by keeping very simple as just a cable.. <...> it’s simple – things can’t go wrong. If we start putting more complex equipment, it’s just more things to go, more things to fail. And the offshore environment is a very, very harsh environment. <....> And it costs an awful amount of money to go out and to repair things out there, because you start and you need a ship like that.. you’ve got to pay probably a quarter of million, half of million pounds just to get a ship like that on site before you do anything else. So that’s why.. even if you keep it simple but you engineer it to a very high level. Onshore something goes wrong.. it’s been a bad day, let’s come back tomorrow and fix it. You can’t do that in the offshore environment, you simply can’t..’. (P4)

At this stage the viability of the ‘socio-material hybrid’ was still hypothetical as Wave Hub was the first project of this kind to be built (in the UK and even in the world). The company started with reviewing the conceptual design of the project trying to improve the viability and updating the cost estimates through re-problematisation. So the black box was opened, and the design of Wave Hub was revised and reengineered. A key problem mentioned was working in the sea (‘harsh environment’). This circumstance was presented as crucial for changes in the design of Wave Hub. With a new set of intermediaries (technical drawings, reports etc.) and its previous experience and skills in the oil and gas industry, the managing company simulated a different translation, which promised the solid result (a reliable working infrastructure) in exchange for reducing the complexity of the overall scheme, and in particular abandoning one of the significant elements – subsea transformers. The task also involved the translation of the interests of the potential customers, as changes in hub’s design – the disappearance of power converting units – could affect their ability to transmit energy to the system. So the negotiation involved a company who was more likely to be the first one to install its devices at the Wave Hub site. What was firmly associated by SWRDA and Halcrow, was dissociated by new actors – a managing company in alliance with the first potential customer whose device did not need transformers on the seabed anymore. The black box was closed, although not properly sealed and leaving a chance to re-open it in the future in case some of the developers wanted Wave Hub to provide PCU for their devices (possibility of which would be decided on an individual basis). SWRDA was persuaded that it was the only way to take the project further, and the decision was accepted by SWRDA.[59]. Finally, this part of the system was agreed and was ready to be aligned with other elements of the actor-network.

The next step was to prepare contract packages for construction and procurement of the equipment on a project and to support SWRDA effectively managing those contracts on their behalf. (P4) The execution of the plan required the extension of interessement – the managing company had to establish new relations and ally new actors to perform the tasks. Since EU funding was involved (through Convergence

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[59] In chapter 6 the change of the conceptual design will be discussed in more detail.

funding for Cornwall[60]), its rules determined the interessment process at this stage – the company was obliged to build those relations through the tendering process. This process requires 'both parties to speculate on the nature of the outcome of the translation and commit upfront to the necessary resources' (Gheradi and Nicoloni, 2005). It was suggested that this uncertainty generated higher risks and increased prices.

Giving an explanation of the difficulties how they experienced them through the construction phase, the participants point to the policy issues at the EU level.[61] '...the public sector across Europe is obliged to offer opportunities right across Europe.. This is the common market.. So we cannot just telephone our friends 'Would you do this for me?'. You know, we have to say 'This is what we want done' and companies across Europe can bid do that. It's very exacting process. And if you want to use European funding, you have to follow that process and it's very difficult to manage this sort of work with that tendering system as well.' (P1)

Moving to the new stage in the project development means bringing new actors in. The amount of work that must be done – the construction of a substation, the drilling, the supply of a cable with specific characteristics, cable armouring, the shipping and laying of the cable, rock dumping above the cable, installing the floating marks in the sea etc. meant the involvement of companies – contractors and subcontractors from the UK and EU. They must be brought together to make the construction happen, and the whole process needed to be organised and managed. With some of the companies JP Kenny collaborated in the past, some were new to projects of such kind and scale.

Thus the new stage involved a further series of negotiations within the actor-network. The various elements in fact affected the construction process causing delays and shifting the starting date for certain operations of the construction work. For example, the delay with the cable manufacturing which was caused by using a new manufacturing facility and a few difficulties related to it. The negotiation involved a

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[60] Convergence for economic transformation. http://www.convergencecornwall.com/
[61] I will pay more attention to this episode in the next chapter.

heterogeneous set of both social and material elements, the managers of the companies and a new manufacturing facility.

As ANT suggests, each actor is at the same time a network in itself. If all elements of the network work well, it performs as a single entity, if breakdown occurs (elements become disaligned) then the network can fall apart. The endeavour to align one of the key elements – the subsea cable – revealed the complexity of one such actor-network. Like all other heterogeneous elements, the cable was in its turn a socio-technical system, a product of further associations of actors, and the processes and mechanisms that were concealed in that black box under the label 'cable' became visible (came to the forefront) when the system malfunctioned. The manufacturer of the cable decided to use the new factory for this operation, and it did not go smoothly. As it was explained, it caused a delay with cable manufacturing and delivery to the site, which in turn led to the revision of a further construction process. Due to this delay there was no need for temporal protection of the cable using concrete mattresses, as the interval between cable laying and rock dumping (used for protection and stabilisation of the cable) was minimal. Elements were repositioned and new translation followed, which actually became a 'lucky' solution for the whole scheme (not to use concrete mattresses for temporary protection but put them on the top of the rocks for stabilisation and longer protection of the cable), as the managers were able to engineer a new solution within the bigger problematisation frame – to build a reliable solid underwater structure.

Delays were presented in the interviews as fortunate for project development. They probably could not be avoided if dealing with different companies-subcontractors. In this situation the delay was fortunate for project developers, as it helped to decrease the cost of the construction operations. The successful outcome was admitted as a result of a contingency concerning the material configuration of the project.

4.6. Uncertain future of Wave Hub

Despite the end of the construction work the project lifecycle has not been fulfilled. The stages of operation and then decommissioning are the future challenging stages where new configurations of an actor-network will emerge.

The intriguing moment, in participants' view, was created for those device developers who were supportive of the idea at the early stage, and how this opportunity will be evaluated in the context of similar projects in other jurisdictions, how Wave Hub actually fits in a bigger picture for industry development.

At the time of investigation the participants acknowledged the state of the project as 'a little unfortunate' as all the berths were empty. The expectations of the managers (i.e. SWRDA) have not been met. They believed in a real demand for the facility and the ability of device developers to raise finance and reach the stage of testing devices in arrays, which would be followed by commercial manufacturing, mass-production and deployment based on the test results at the Wave Hub site: '...When we started Wave Hub, we kind of thought that it was just a few years away, it's probably a bit further than that...'.

This situation represents, probably, the most significant 'failure of enrolment'. The managers of the project attempted to align the device developers from the beginning as potential users of the facility. The focus of interest was on those who were believed to have devices which were at the most advanced stage of development. So the core of those relations was always a technical artefact. Four device developers were chosen as the first customers for Wave Hub at the planning stage. But by the time the facility had been built, only one of them had an intention to install its devices at Wave Hub. Due to different reasons (as explained by the participants – one company got bankrupt, another experienced technical problems with its device and reviewed the potential advantages and disadvantages of using the facility not in favour of Wave Hub) three initial customers – companies withdrew from the project. In the case of the WECs it was recognised as evident that device developers were 'overoptimistic' about their devices and companies' potential to take them further to that pre-commercial stage when they can be installed in arrays at the Wave Hub site. The devices, in fact, were in turn the result of other associations that at a certain stage came to the fore. Like all other heterogeneous elements that made up the actor-network, the devices (WECs) turned out to be socio-technical systems. The processes and mechanisms that stand behind each of them and that were concealed under the label ‘wave energy converter’, suddenly became visible. There are elements like funding, research activities, managerial decisions etc. that became important. Therefore this enrolment also partly failed, and it was necessary to go back to the negotiation process and look for new alliances.

The participants suggested that at the moment the main problem for device developers (and consequently for Wave Hub) would be finance. Marine renewables compete with a ‘buoyant’ offshore wind industry for investments, as the latter is seen as more secure and technologically proven, despite its inefficiency. Wave energy is perceived as a nascent industry and it is just growing, but uncertainty for investors and the risky nature of the wave energy industry were seen as serious obstacles for further development. Nevertheless, the belief is still there that wave and tidal energy ‘will be of a similar price to the consumers’, and will become ‘economically justifiable’. It was believed that Wave Hub would be populated eventually, and it is only a matter of time.

Using the terminology suggested by Pinch and Bijker (1989), the finalised construction of Wave Hub illustrates the stabilisations of an artefact, which leads to ‘closure’ in technology when the relevant social groups see the problem as being solved. The question of closure often occurs during the project when the problems of different kind and scale must be solved and, more important, presented as such. An attempt to ‘close’ the ‘environment problem’ by simply claiming that the technological project does not cause any harm to the environment is a good example of rhetorical closure. The elements of rhetorical closure also present as part of the solution for situations where controversies cannot be solved through negotiation (e.g. the situation around shipping routes). Closure by redefinition of the problem – the distance from the shore is a problem for some device developers and might increase maintenance costs, but can be seen as an advantage in terms of ‘out of sight’ for the general public (the meaning of this decision was translated to constitute a solution to quite another problem).

Compromising, according to Latour (1996), is the only way to increase a project's reality. And the case of Wave Hub perfectly illustrates different 'sociotechnological compromises'.

The process of negotiations, compromises, arguments and conflicts during the implementation of the project led to stabilisation of the relationships surrounding it. In this chapter I discussed the decisions and power relationships through which actors gradually agree on, going from the very idea of the project to its realisation, and how the relationship surrounding the project were stabilised. It can be claimed that Wave Hub is 'society made durable' (Latour, 1991) insofar as its design and implementation reflect the process of its unique creation, embodies social relations that were translated into a material form of the project.

Materialisation can be understood as a gradual transformation of the idea into its material realisation (Jolivet and Heiskanen, 2010). The story of Wave Hub illustrates materialisation of this project and the associated devices and instruments used to bring together the necessary actors and technology. The whole project (Wave Hub), the ideas, inspirations and energy of people were materialised in built infrastructure (subsea cable, hub and substation). May be even more, the potential of the UK as a leader in marine energy and its future, ambitious plans, policy mechanisms – all of these elements were materialised in that cable on the seabed. But this physical object does not do anything itself; it is an infrastructure according to its purpose. As an infrastructure, Wave Hub can produce certain integrations and exclusions, and it would be not analytically productive to consider it separately from its users. It is both sequential in relation to the development of science and industry, as well as enforcing, as it tells the users what they can and cannot do at Wave Hub (boundaries). At this stage Wave Hub became an incentive cause, an inducement for device developers and scientists defining a programme of action for many players in the offshore renewable sector.[62]

[62] Wave Hub, being an actor-network, can also be seen as a simple link in a chain which extends from the consumer of electricity produced at Wave Hub to the generating company/companies, a simple intermediary (an instrument or tool). This ambiguity can be explained whether the focus is on the (technical) object/network itself ('a dignified actor') or on the networks that lie beyond (Callon, 1991).

It is suggested that a technology 'should be understood in terms of its relationship with other entities of its phenomenal world' and that 'the sense of context and machine mutually elaborate each other', especially emphasising a tie with a user (Grint and Woolgar, 1997, p.72). Wave Hub, since it has been built, has become itself an interessement device aiming to attract and enrol device developers and stimulate certain activities.

Now device developers come to the front stage, and Wave Hub will be on trial once first wave energy converters are installed. It is argued that the character of potential users, capacity and possible behaviour are defined in relation to the technology (Grint and Woolgar, 1997). In case of Wave Hub, the potential users (or customers) were explicitly articulated since the beginning of the project. Although the potential users were part of the socio-technical relations embodied in Wave Hub at the early stage (as their preferences were investigated when the concept was being elaborated), now their role as users of the facility positions them as key elements in/to (new) network configuration. It also makes possible 'a detailed and contemporaneous assessment' (ibid.) of this infrastructure/technology at work, its usefulness and viability.

It can be suggested that the boundaries of Wave Hub, which are partly shaped through its purpose and decisions about its design, were created/configured on the basis of industry's needs when developers who showed the greatest interest in this facility were targeted. When the project, including its technical design and location, was stabilised, it itself became a restricting tool or framing 'technology' for the wave energy industry limiting device developers in their ability to use the facility – only those who have particular type of devices can benefit from using Wave Hub (e.g. WECs that require certain depth as nearshore devices are excluded in principle, and those that have reached pre-commercial stage when devices can be tested in arrays). This in turn can work for stabilisation of certain technology types (WECs) which would get an advantage on the market through the use of the publicly-funded facility that can help in commercialisation of the devices. Thus, those device developers whose voice was heard by SWRDA at the initial stage of the project development can gain extra tool for establishing their domination in the sector.

Entering into contractual arrangements with device developers ('customers')[63], Wave Hub is being transformed into a commercial enterprise: an underlease and a birthing agreement are to set down the respective responsibilities of Wave Hub and its customers – device developers[64]. Besides, according to a power purchase agreement that Wave Hub will enter on behalf of its customers, customers will receive a share of the sale proceeds of power, renewable obligation certificates, embedded generation benefit and other receipts according to the amount of power they have generated.

Not only materialisation but also dematerialisation plays a role in lifecycle of a technology. To finish the story of a macro-actor, it is necessary to say a few words about the proposed end of the lifecycle of Wave Hub. Deconstruction of a material form of a macro-actor (or dematerialisation of Wave Hub) will be implemented in decommissioning of the facility and WECs[65]. Thus, decommissioning is another aspect of the Wave Hub future which is needed to be envisaged and incorporated in the overall picture. The decommissioning plan represents a scenario about how the project's cycle is fulfilled and how the physical implementation of a macro-actor is deconstructed.

At the stage of decommissioning the careful deconstruction of the material form of Wave Hub is planned. It presents removal and disposal options for different parts of the facility which is in turn divided into four categories: offshore infrastructure, onshore infrastructure, cable and WECs. Wave Hub is perceived in terms of the items to be decommissioned and the materials they are made of. As such, the physical implementation of a macro-actor breaks up into a number of elements such

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[63] 'OceanEnergy Ltd has been granted a three year marine license for the deployment of the first wave energy device at Wave Hub. The Marine Management Organisation (MMO) has granted consent to Cork-based OceanEnergy Ltd (OEL) to deploy its €9 million OE Buoy wave energy converter at Wave Hub, around 10 miles off the north coast of Cornwall in South West England.' Source: Marine licence approved for first Wave Hub deployment. 8th January 2013 http://www.wavehub.co.uk/news/press-releases/marine-licence-approved-for-first-wave-hub-deployment/

[64] Wave Hub. *Commercial Terms for Developers*. http://www.wavehub.co.uk/information-for-developers/commercial-terms/

[65] Halcrow Group Ltd/SWRDA, 2006. Wave Hub Development and Design Phase. Final design report. Appendix B. Decommissioning Plan. http://www.wavehub.co.uk/wp-content/uploads/2011/06/Wave-Hub-Final-Design-Report.pdf

as substation building, cable trenches, PCUs, cables between WEC umbilical and PCU, navigation buoys, moorings, anchors and so on.

Can we say that this macro-actor will disappear then or still will exist in another form or change its configuration, e.g. through its impact and functions it performs and results it helps to gain? Will the actor-network be falling apart or being transformed through punctualisation effect when it will become an element of another growing network – a wave energy sector? The possible history of Wave Hub helps to raise further questions about materiality, e.g. through the lenses of sociology of expectations, as I will discuss in the next chapters.

4.7. Conclusion

The process of constructing an actor-network, as we can see from the story of Wave Hub, was not a simple linear process comprising of four clear cut stages of problematisation, interessement, enrolment and mobilisation. As Callon (1986) suggested, these stages can overlap. Moreover, for building a macro-actor (which is comprised of a number of black boxes), a multitask translation is to be pursued where these processes can occur in parallel with regard to different actors and different tasks, overlap, be repeated or re-done etc.; interessement devices might not be sufficient, actors can refuse the imposed identity and roles, enrolment can fail, re-problematisation occurs and so on. Every black box closed supposes to have its own finalised translation process under its lid.

Natural resources (‘an excellent wave climate’) available, the electrical grid, the availability of financial resources and ‘Government push’ introduced an initial frame of problematisation by suggesting the option of wave energy project. But as the analysis shows, there was nothing at the beginning that would allow an observer to foresee the final outcome of the project, the way it would go and all the contingencies that could change its trajectory. It became a macro-actor because it succeeded in recruiting others to its cause (presenting it as worthwhile). Many times during the story weak reversible interactions were replaced by strong interactions, a variety of possibilities was turned into a clear trajectory, a line of forces and obligatory passage points.

The complex interaction and translation of different elements of an actor-network were orchestrated in large part by the management team. Their task was to align and interest the network's various social elements, human and non-human. As such, one can talk about 'heterogeneous engineering' of Wave Hub as a macro-actor. The participants themselves recognised the importance of the 'socialities' (i.e. social elements) for the project, building a network and negotiation process, as well as uncertainty constantly presented there, agreeing on the fact that the technical side of the project was 'only a half of a story'.

There was no one in a position to talk to SWRDA on behalf of nonhumans (i.e. waves, transformers, species) at the beginning of the development. The scientists and consultancies involved (including PRIMaRE) studied biodiversity, wave climate, electrical engineering etc., and prepared a number of reports, articles and studies. As such, they became similar to intermediaries and were in the position to talk on behalf of non-human actors, as translation is 'a process that operates on both social and natural entities' (Law and Callon, 1989, p.64).

Thus, besides SWRDA and key actors (e.g. Halcrow or JP Kenny), the actor-network comprised a variety of other human and non-human elements, which included other companies – contractors and subcontractors, the weather and seabed conditions, the cable and the new manufacturing facility where it was produced, the vessels, rocks and concrete mattresses, the skills, the existing regulations and financial resources (which were limited), the existing power station etc. The task was to align and interest the network's various elements (social and technical, human and non-human), to orchestrate their interactions and translations. The actor-network composed of these elements became a collective creator of Wave Hub.

The emergence of a macro-actor construed certain actors as having a voice in the project. These social groups (especially local groups such as fishermen, surfers, local business) had to be convinced if the project was to be successfully implemented, and the consenting process was the biggest trial of strength for the actor-network. It was being challenged by the regulators, and other entities were assisting them. Eventually consensus about various aspects of the project was achieved; the network resisted and proved its strength, although a few significant failures of enrolment happened (i.e. PCU, device developers). For example, the enrolment of one of the key elements of an underwater system – transformers – failed, which entailed a re-negotiation of the design at the later stage. These failures posed questions about credibility of the project and legitimate decision-making at different stages of the development.

It is apparent that the expert knowledge played a crucial role throughout the project. Using an analogy with St Brieuc Bay (Law and Callon, 1989), it is possible to say that Wave Hub was converted into a machine for producing information (numbers, documents, studies) and knowledge (marine environment, engineering, wave climate), speaking in the language of science.

In a possible history of Wave Hub policy also emerged as a significant part of participants' discourse describing a macro-actor. Both UK and EU regulations played an important role in developing a framework for the project (e.g. EU funding) and even defining its trajectory at some points. To develop the analysis of the prominent aspects of the construction of Wave Hub as a macro-actor, I discuss particular aspects of Wave Hub discourse – policy, credibility and expertise – in the following empirical chapters.

Chapter 5. Policy as an actant: from scale to agency

'Policy changes as it moves, and the more it moves the more it seems to change. <...> It must change in order to move, and it must move in order to exist.'
Freeman (2012)

5.1. Introduction

The analysis around the concept of a macro-actor, introduced and elaborated in the previous chapter, helped to explore the emergence of Wave Hub as a macro-actor and to examine numerous controversies about its design and destiny. The purpose of this chapter is to investigate an analytical approach to policy as an actant. As discussed in the literature review, the notion of an 'actor' is central for actor-network theory. It is seen as a semiotic definition in ANT defining 'something that acts or to which activity is granted by others' (Latour, 1997). Michel Callon (1991) defined an actor as 'any entity that more or less successfully defines and builds a world filled by other entities with histories, identities, and interrelationships of their own' (Callon, 1991, p.140). Actors can be human and non-human, can have variable content and variable geometry; they might be hybrids or collectives, not necessary though (ibid.). The ideas of agency and authorship aid understanding of the concept of an actor. An actor can be a principle author of actions in a network. As Callon (1991) stated, '*an actor is an intermediary that puts other intermediaries into circulation* – that an actor is an author' (ibid., p.141). In other words, all actors might be viewed as intermediaries, links in a chain which both connect and define the relationship between the agents concerned, and sometimes they can be treated as actors, as the principle authors of particular effects (Newton, 1996; Callon, 1991). The notion of actants is used in ANT, substituting the notion of an actor to emphasis the agency attributed to entities, when they perform as a source of action.

From the perspective of symmetry in heterogeneous networks (Callon, 1986) I will assess the role of policy as an actant in a network and examine its performativity, in particular the relationship between political decisions and the development of Wave

Hub, as well as a possible reverse effect that it might have on policy and regulation in the field, causing some changes and transformations of a policy network.

With this in mind, the central questions to be investigated in this chapter are to what extent, and in what sense, policy can be understood as an element of an actor-network, not merely a 'context' in its conventional understanding. Furthermore, this approach will help to build a discussion around the evolution of the actor-network with policy as its active element and critically assess to what extent this approach might help to understand the destiny of a technological project.

My approach differs from current analytical approaches in energy policy studies. To date, a more conventional analysis of policy using concepts of authority, power and legitimacy (and categories of governance, conflict resolution, political institutions, public participation, implementation etc.) dominates. As it was suggested in literature review, there is a clear divide between micro and macro scale, and policy is often understood as a macro context, as an institutional and regulatory framework (i.e. something is happening in the context of macro).

The idea of level of analysis, however, can be questioned from an actor-network theory perspective. In my research I employ a different approach to policy and try to re-think the ways for analysing it from a new perspective. I am trying to develop an actor-network approach employing the concept of a macro-actor. This implies an analytic possibility to reject commonly assumed *a priori* distinctions between micro and macro and of an idea of a 'macro context'. Such actor-network theory approach allows one to dissolve the micro/macro distinction, as applying ANT a metaphor of scale is replaced by a metaphor of connections (Latour, 1997).

As discussed in the literature review, in social science studies contexts are recognised as social constructs and as a non-static emerging phenomenon (e.g. Augier et al, 2001). It is also an individual construct based on the individual's previous experience (ibid.), and it can be seen as a result of prior interpretations (Dilley, 2002). Context is also a relational thing and can be thought in terms of connections and disconnections, seeing context as a set of relations and not self-evident thing in itself (ibid.).

STS scholars suggest a symmetrical approach to context and content (based on the ANT principle of generalised symmetry). ANT is seen as 'anticontextualizing': both content and context are 'jointly created in a single process' and that context is 'internalized in the object' or, in other words, 'the local network contains the global network' (Asdal, 2012, p.296). From ANT perspective, successfully translated actors (mobilised without contradiction and reduced to 'stable and predictable entities', monoliths) constitute the context of a particular project as they become part of the background (Law and Callon, 1989). By contrast, complex and intractable networks that still require translation are the focus of attention and constitute the content of the project. Thus, the context itself is understood (which might include social and economic relations etc.) as something beyond the 'negotiation space', and the mobilised actors create a context for the growing network (macro-actor) (ibid.).

In this chapter I refer to the problem of context in STS debate and the ANT approach to this category as a theoretical basis for exploring a question of policy as an actant. As an introduction to the analysis of my empirical data, I will discuss in brief the wave energy industry and renewable energy policy in the UK, analyse policy discourse and renewable (wave) energy as a policy category. I will then introduce the main themes and key ideas from my qualitative data. Discussion based on the concept of context and micro/macro distinction in ANT will follow. I will also discuss the notion of policy and its meaning for the purpose of my research. The analysis of the participants' discourse on policy and related issues will help to answer questions about policy as an element of an actor-network, to discuss the role of policy as an actant in the construction of a macro-actor and the role of promissory discourse in building credibility of the Wave Hub project.

5.2. Expectations and renewable energy policy: the promissory discourse

The renewable energy policy in the UK is seen as a product of significant political changes and reforms, including market liberalisation and privatisation of state controlled energy companies during the 1980's and 1990's, and the rise of climate change concerns and the role of sustainability agenda.

The beginning for policy support for renewable energy can be traced back to 1990 when the Renewable Non-Fossil Fuel Obligation (NFFO) was set up.[66] Although this mechanism was not particularly successful (Connor, 2003), it marked a start of a delivery programme for renewable electricity in the UK. Since 1990, the UK Government has re-adjusted its renewable energy policy several times; the design and cost of such policy shifts, as well as the lack of clarity and agreement over the goals, were criticised and seen as constraining successful development and deployment of renewable energy in the UK (Mitchell and Connor, 2004).

In the early 2000's climate change debates affected the energy agenda and policy in many countries, including the UK, and interest in renewable energy increased due to UK targets for reduction of carbon dioxide emissions (in line with EU targets). As a result, in 2003 the UK Government published a visionary energy policy placing the UK on a path to cutting carbon dioxide emissions by 60% in 2050 (ibid.). The white paper on energy 2003 'Our energy future – creating a low carbon economy' marked a new turn in energy policy in the UK in light of climate change and carbon reduction confirming an official commitment to sustainable development. It was based on four pillars – the environment (reducing carbon emission), reliability of energy supplies, affordable energy and competitive markets; a recurrent theme through the document was 'cleaner smarter energy' (DTI, 2003).

Despite the attempt to set a long-term framework that would provide confidence for various players, there was a lack of detailed policy responses to the challenges the UK was facing in meeting its energy policy goals. The next white paper published in 2007 'Meeting the energy challenge' aimed to address the challenges the UK faced in light of the changes in energy sphere, such as aging nuclear power infrastructure and falling gas supplies from the North Sea. In this document the Government announced the intention and responsibility to create the right incentives and framework to enable a rapid transition to a low carbon economy. The Government confirmed its commitment to renewable energy as playing an important role helping

[66] Although the NFFO was primarily set up as a means to subsidise nuclear generation, specified renewable energy technologies were included in the definition of eligible non-fossil fuel technologies in the Electricity Act 1990.

the UK meet its energy and policy goals, and reconfirmed the policy context for planning and consent decisions on renewable generation projects. It announced the support for new renewable energy projects, which might not convey visible local benefits but would provide crucial national benefits helping to reduce emissions and diversify energy supply. Therefore, it was recommended for the planning system to give a significant weight to this factor when considering renewable energy proposals (DTI, 2007).

The transition rhetoric was reinforced in the UK Low Carbon Transition Plan 2009 which plots how the UK intends to meet the 34% cut in emissions on 1990 levels by 2020, and in particular, includes the aim to increase renewable electricity to 30% by 2020. This document shows how reductions in various sectors could enable carbon budgets to be met and describes the actions to be taken, which are seen as necessary for the transition to a low-carbon economy (DECC, 2009). It is suggested that this transition would give a chance to lead the clean industries for the future, e.g. CCS. The Plan is an overarching document and a number of more detailed documents were published alongside it, including the UK Renewable Energy Strategy.

The Renewable Energy Strategy published in 2009 sets out the roles individuals, communities and businesses can play in promoting renewable energy and achieving greater renewable energy deployment. As an element of the overall transition plan to a low-carbon economy and sustainable future, the document suggests a scenario where more than 30% of electricity and 12% of heat would be generated from renewables, and 10% of transport energy would come from renewables. The important part of the strategy is the Government's commitment to develop mechanisms to provide financial support for renewable electricity and heat (e.g. introducing Feed-in Tariffs) and to provide greater support for key technologies, i.e. to increase investment in emerging technologies such as wave and tidal generation, to make improvements to offshore wind technologies and to develop more sustainable advanced biofuels (DECC, 2009).

This brief overview shows that the overall policy framework for renewable energy in the UK has been developing in close correlation with climate change agenda and carbon reduction targets. The implementation of these strategies required clear mechanisms in order to deliver the ambitious goals announced by policy-makers.

In this section the state of the wave energy sector and renewable energy policy in the UK will be discussed. This includes a brief analysis of the level of technological development, challenges and 'endemic' problems for the sector, the renewable energy policy and regulatory mechanisms in the UK at the time of the field work, including economic instruments. I will also analyse policy discourse associated with renewable energy, and in particular, wave energy, and how renewable energy as a policy category is constituted and stabilised.

5.2.1. Policy discourse and stabilisation of renewable energy as a policy category

5.2.1.1. Wave energy: promises, uncertainty and expectations

It is often argued that ocean (or marine) energy is amongst the most under-explored, and certainly the most under-utilised source of energy. Ocean (wave and tidal) technology could be much more reliable and predictable than other kinds of renewable energies, such as wind or solar; coupled with vast worldwide resources (2,000 TWh[67] to 4,000 TWh yearly), ocean energy may be the key to answer the world's escalating energy needs[68].

Waves are not the only type of marine energy; there are other forms of ocean energy such as tides, currents, salinity gradient, and thermal gradient or ocean thermal energy conversion. Due to the specific of the case study, considered in this thesis, the focus in this chapter will be mainly on wave energy (which is produced by surface gravity waves and are wind induced)[69] and issues derived from it (industry, technology, policy). However, some data used in this chapter cannot be

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[67] Major energy production or consumption is often expressed as terawatt hours (TWh) for a given period that is often a calendar year or financial year. One terawatt hour is equal to a sustained power of approximately 114 megawatts for a period of one year.
[68] Frost & Sullivan '*Hydro, Wave, and Tidal Power--Market Penetration and Roadmapping*. http://www.technicalinsights.frost.com
[69] Wave energy is the extraction of useful energy from the motion of water in surface water waves on the sea (DTI, 2005).

differentiated by type of ocean energy and includes other sources beside waves (e.g. renewable energy policy often addresses wave and tidal stream together).

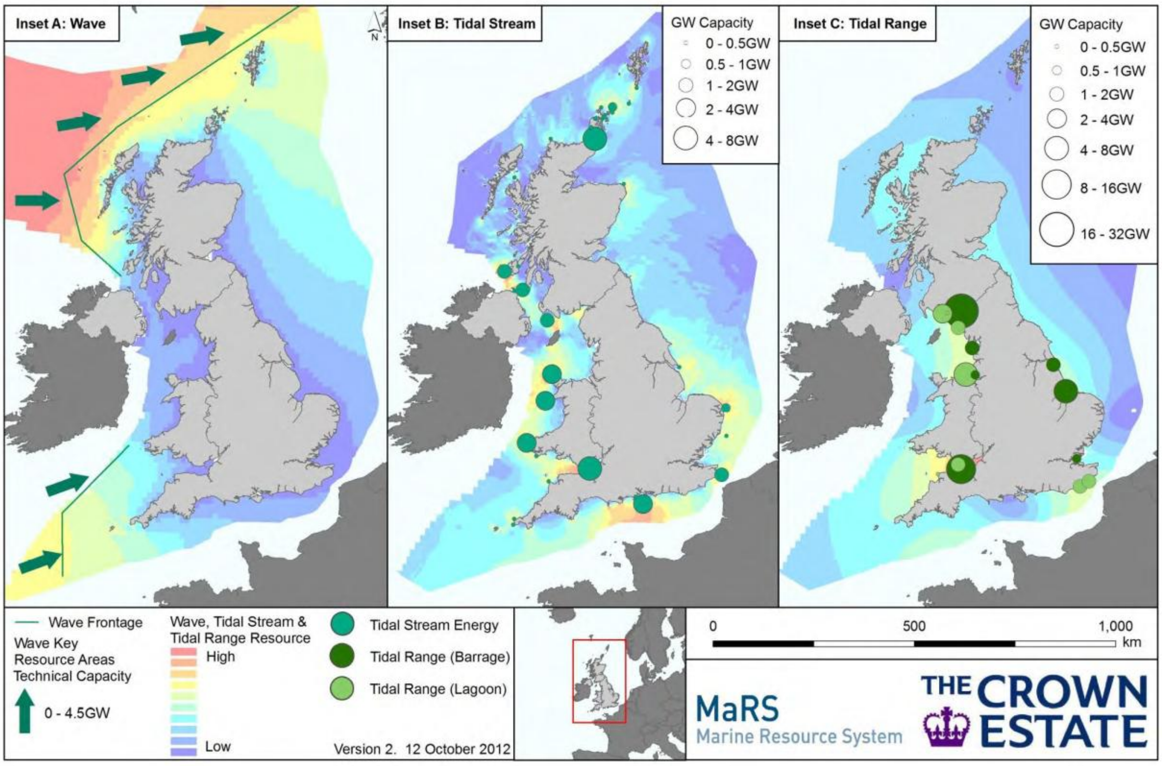
There is a general consensus in published reports that the UK has significant potential for wave, tidal stream and tidal range generation (e.g. The Crown Estate, 2012; Committee on Climate Change, 2011; The Offshore Valuation Group, 2010; Renewables Advisory Board, 2008). According to the Offshore Valuation Group[70] (2010), the average wave power entering the UK waters is 40W/m, coming primarily from a North-Westerly direction. On the basis of theoretical calculations and primary field data, it was suggested that the practical potential for wave energy is considered to be 40 TWh/year, which is translated into an installed capacity of approximately 18GW (The Offshore Valuation Group, 2010). Marine energy could contribute up to 20% of UK electricity needs (Renewables Advisory Board, 2008). A large share of the total generation is expected to be located in three regions in the UK: off the coasts of western Scotland, south-west Wales and Cornwall (ibid.). The potential for tidal range exploitation around the UK was also estimated at around 40 TWh/year, although it was seen as more uncertain due to uncertainty around the correct physical estimation methodology, with estimates ranging from 18-200 TWh/year (Committee on Climate Change, 2011).

The Crown Estate report on wave and tidal resources in the UK contains the latest findings (theoretical estimates) about the size and distribution of wave and tidal resources available in broad geographical areas around the UK (The Crown Estate, 2012). The figures here seem to be more significant than earlier estimates. Total theoretical UK resources are estimated to be for wave energy 69 TWh/year (27 GW)[71] where 23 TWh/year (8.7 GW) is for England and Wales; for tidal stream 95 TWh/year (32 GW); for tidal range (barrage scheme) 96 TWh/year (45 GW) and for tidal range (lagoon schemes) 25 TWh/year (14 GW). It is also suggested (without considering practical constrains to development) that there is likely to be a larger

[70] The Offshore Valuation Group is an informal collaboration of government and industry organisations that have come together to address the question: what is the value of the UK's offshore renewable energy resource? http://www.offshorevaluation.org/
[71] Figures are stated in terms of both annual energy (TWh/year) and power (GW) (The Crown Estate, 2012).

number of potential sites for wave energy projects than tidal ones (ibid.). The diagram below provides an illustration of 'regional breakdown' with wave resources mainly distributed around the northwest of Scotland, southwest Wales and southwest England.

Fig. 2. Distribution of wave, tidal stream and tidal range energy resources[72]



On the basis of such evaluations attempts have been made in various public reports (including policy documents) to put a value on what the renewable energy resource around the coasts might bring in terms of creating jobs, investment, infrastructure creation, revenue, as well as clean and affordable energy. The debate in the UK around marine energy on how to best maximise offshore resources and secure future energy supply also focuses on reinforcing manufacturing base which would provide an opportunity to establish the UK as global centre of the future marine energy industry. It makes the question of developing marine energy technologies

[72] Source: The Crown Estate, 2012.

central in this debate. In the UK wave and tidal stream technologies are talked about as being at the demonstration phase; they are expensive but promising, given significant resource potential and scope for cost reduction (Committee on Climate Change, 2011).

As a result, the main characteristic of wave energy discourse is that it exhibits a strong promissory rhetoric framed in terms of both economic viability and technical expertise. It is said in both the literature and the interviews with participants, that its future remains uncertain and heavily depends on public and private funding; there are significant resources distributed globally and a vast array of wave energy technology promoters with highly differentiated technology designs, but none of them is commercially viable yet, although several wave energy technology companies claim to be near commercialisation (Global Ocean Energy Markets and Structures: 2010-2030, 2010). This includes several UK device developers who managed to emerge as 'technology front-runners' pioneering deployment and environmental monitoring techniques required for large scale commercialisation (Vantoch-Wood, 2012).

It is often claimed that wave power technologies have only started developing, and as with every other energy source a certain maturity is needed before widespread commercialisation. As a representative of one of the 'technology front-runners' suggested, from a strategic perspective it [the wave energy industry] is fairly immature; there is no commercial deployment, and only limited operational data and limited operational success. (P22) It is argued that its ultimate competitiveness depends simply on the technology's ability to be relatively cost effective versus fossil fuel sources. For wave energy technologies, as for other renewable, 'the only significant commercial issue that needs to be addressed is price: the unit cost of electricity produced' (Denniss, 2009).

At this stage of development in the wave energy industry, promises and expectations are a part of the articulated belief in its potential and the basis for continued support. It could be argued that the industry is supported largely because 'certain world-views became dominant in the policy sphere, and these world-views are among the things that keep it going' (Galvin, 2009, p.4). As such, the concerns about climate change, energy security and anticipated economic benefits play the main role; the climate change mitigation goals have become a sort of 'ideological' basis for the renewable energy policy in the UK.[73] This also can be identified in European policy directives and related rhetoric. The case study of Wave Hub is an illustrative example, where the intention to fund projects in 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'. (P13) In this sense, it is possible to say that EU and UK climate change goals (for future reduction of CO_2) were translated into renewable energy initiatives which became a present concern.

5.2.1.2. Constitution of renewable energy as a policy category

To understand renewable energy (and wave energy) as a policy category it is necessary to analyse policy discourse associated with renewable energy in the UK. For this purpose I present a critical assessment of the terms in which renewable energy (and wave energy) is constituted in policy discourse. In its most concentrated form policy discourse is represented in texts of relevant documents – policy statements, strategies, plans and related legislation, which depict particular policy understanding of renewable energy in the UK.

How do we identify policy documents as being relevant to renewable energy given various sometimes unrelated framings of problems that wave energy policy is trying to find solutions for? In this dissertation different areas of public policy and governance are presented as relevant to and/or having impact on the development of wave energy in the UK, such as policies on innovation, research and development, environment protection, investments, market policies or licensing. Besides, wave energy is often considered and addressed as part of a more general domain of renewable energy and is not always singled out (e.g. the issues which can be seen as relevant to the whole renewable energy sector, such as the Renewable Obligation). In this sense, it becomes a part of a complex set of narratives created by

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[73] The UK has clear legal obligations to deliver more electricity from renewable sources which derive from both European and national legislation.

policy-makers and linked to each other with various degrees of success. Wave energy in policy documents is largely defined as part of ‘renewable energy’, as part of ‘marine energy’, or can be singled out as simply ‘wave energy’, and overall policy discourse around wave energy is an aggregation of these different but interrelated domains. However, there are instances of less purified view of wave energy as it is coupled with, or discussed in conjunction with, wind energy. The place of wave energy in the family of the emerging renewable energy sector makes it the opposite to conventional sources of energy such as oil and gas, even if, as some critics say, some expertise of offshore oil and gas is transferable for the wave energy projects (Simakova and Iskandarova, 2013).

In this study I mostly focus on those policy documents and other policy-related sources (e.g. consultations) which have direct bearing on both renewable energy and marine and/or wave energy. It is common to find renewable and/or marine energy to be announced as primary subjects of such documents, which is reflected, as a rule, in documents’ naming (e.g. Marine Energy Action Plan 2010; the UK Renewable Energy Strategy 2009).

In the UK energy is pronounced as being at the top of the policy agenda and presented as a matter of ongoing policy concern. It became one of the core elements of security and sustainability discourse, where renewable energy is presented as a solution to a two-fold problem: tackling climate change by reducing emissions, and ensuring secure energy supply through diversification of energy sources.

As such, the common rhetoric surrounding renewable energy in policy documents is based on general themes of sustainability and climate change, and includes speculations about low carbon energy economy, green energy, diversification of energy sources and security of supply, as well as rhetoric of innovation and economic growth. A strong moral component in the rhetoric is associated with environmental protection and job creation.

Corresponding with Webster’s (2007) suggestion, one could refer to renewable energy as the field of emerging technologies framed as a ‘policy object’. It is important to note that the politicisation of renewable energy – meaning that renewable energy has become an object of policy and politics and subject to state regulation – is quite advanced when a degree of politicisation is high[74]. As a rule, policy documents employ a set of categories and tools to construct a policy object (or even a field): a rationale, targets, concepts, instruments (e.g. economic instruments), and relevant stakeholders. These categories help to map up the area that is considered as requiring policy attention (intervention, regulation and/or control) including technological and economic activities.

Proposed policy measures are declared to stimulate the growth of the wave energy industry. The development of the sector is largely described through providing funding and encouraging university-industry relations, all leading to societal benefits. These benefits can be new, diverse types of energy to tackle issues of climate change, achieve energy security and gain economic benefits (Simakova and Iskandarova, 2013).

Narratives can be clearly identified in policy documents and can be seen as ‘authoritative endorsements’ (ibid.) and a guideline for development of the industry.

The typical feature of policy documents in the field is justification of the importance of the area of renewable energy (or a particular source of energy, e.g. wave energy), suggested potential and anticipated benefits for the economy and for society, as well as the statements about resource availability in the UK. The pronouncement of the achievements and the ‘leading’ role of the UK, which is recognised as being at the forefront of the marine renewable energy industry through its research and development programmes and test facilities, also has become a common

[74] Although I would argue that talking about renewable energy as a policy object is not absolutely correct from the legal point of view, as the object of regulation is not renewable energy, or wave energy, *per se*, but the social relations on and around renewable energy and how it is situated within the wider network (or ‘sociotechnical system’ as in Webster’s work) of ‘UK energy’. To justify such an approach a concept of ‘object of law’ can be used. The object of law is one of the basic systematic concepts of jurisprudence, closely linked with the concept of a legal relationship and a legal subject (Pashukanis, E., 1927. *The Object of Law.* http://www.marxists.org/archive/pashukanis/1925/xx/object.htm). It is accepted that object of law is social relationships which, in given socioeconomic and political conditions, are subject to legal regulation. This approach has been adopted in other fields beyond law. For example, Bateson’s suggestion that what can be studied is always a relationship or an infinite regress of relationships, never a “thing” is also aligned with this approach (Bateson, 1978, p.249). Nevertheless, in this thesis I will use the more common phrasing regarding regulatory and policy objects for convenience of narration.

introductory statement in policy discourse. It is often claimed by the policy-makers (and reflects their inspirations and expectations) that the UK is a world leader in this field, and the aim is to remain in a leadership position in the future. It is believed that the UK has a 'comparative advantage' in developing marine energy technologies (as well as offshore wind), and should support them to be a leader internationally (Committee on Climate Change, 2011).

The UK's Coalition Government, formed in 2010, made a pledge to be 'the greenest government ever', and the Coalition Agreement states: 'We will introduce measures to encourage marine energy'. Although this is often questioned and the Government is criticised for pursuing an anti-renewables agenda, the rhetoric remains the same. It is claimed continuously, that there is a political will for the UK to be 'the best place in the world to invest, deploy and commercialise these technologies' sending, as the Government believes, a clear signal to tidal stream and wave industry (Chris Huhne, Secretary of State for Energy and Climate Change, 2010-2012)[75].

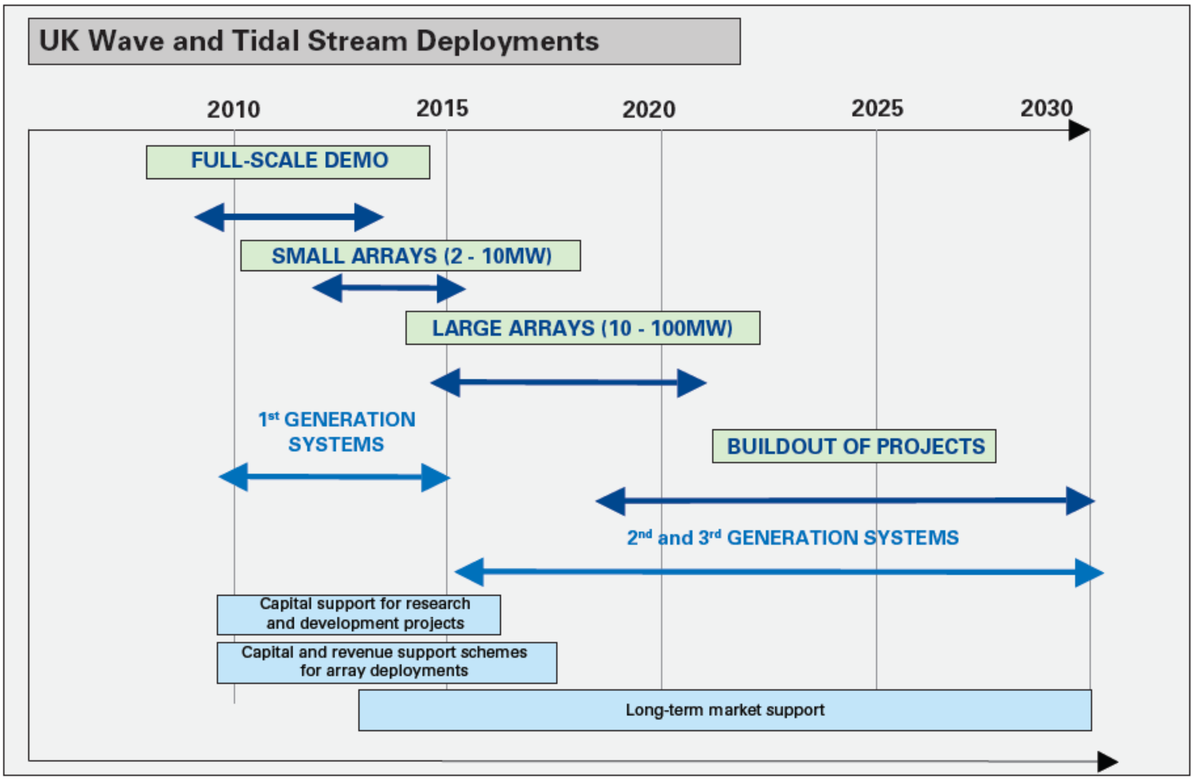
'Revolutionary' rhetoric, based on the recognition of challenges on the way to low carbon futures, is complemented with speculations about anticipated desirable shifts and significant changes in energy systems (e.g. 'Transforming our power sector'). Although new emerging technologies (e.g. wave energy devices) play a crucial role in development of wave energy sector, some assessment categories, such as risks, are marginalised.

Timeframes are important components of this rhetoric. In policy documents activities and scenarios are defined through future-oriented statements (e.g., low carbon transition plan to 2020; developing a roadmap to 2050) and strategic visions. Among policy initiatives in the UK, which employ timeframes in regard to marine energy in recent years, the most illustrative is, probably, the Marine Energy Action Plan 2010 (MEAP). This policy document is presented as a result of a collaborative process between Government and industry to set out an agreed vision for the marine energy sector to 2030. The diagram below provides a good example of strategic planning

[75]Chris Huhne's speech to the Renewable UK Conference, 26 October 2011 http://www.decc.gov.uk/en/content/cms/news/ch_speech_ruk/ch_speech_ruk.aspx

and visualisation of wave and tidal energy technologies development produced as a foresight by policy-makers.

Fig. 3. Potential Deployment plan for wave and tidal stream technologies out to 2030[76]



Relying on promissory rhetoric and credible narratives of economic viability and technical expertise, the vision of the future in policy discourse is constructed through announcement of 'ambitious targets' (or 'challenging targets'), which are widely used in policy documents (e.g. '15% of energy from renewable sources by 2020'[77]). Performing as anticipated outcome of the policy provided by the Government, these targets become, in certain way, a concentrated symbolic representation of future-oriented policy agenda in the field of renewable energy. Moreover, the construction of renewable energy futures (or a particular vision of energy future), which include

[76] Source: DECC, 2010. *Marine Energy Action Plan*.
[77] UK renewable energy targets are formulated in line with EU Renewable Energy Directive (to source 20% of the EU's total energy consumption – a combination of electricity, heat and transport – from renewable sources by 2020).

expectations and their assessments, is largely performed through numerical description – percentages of emission cuts and energy or electricity coming from renewable energy sources, numbers regarding jobs that can be created and value for the UK economy. Such energy scenarios help to mobilise financial and political support for renewable (and wave) energy and a preferable vision of the future is supported in policy discourse (e.g. 'our lead scenario' as in The UK Renewable Energy Strategy 2009).

Documents present such policy visions as being informed by exact science where scientific discourse is widely employed to describe the sea in ways acceptable for policy purposes. It is suggested that policy usage of scientific-sounding terms can help to garner legitimacy and helps it to succeed (Yanow, 2011, p.309). The widespread understanding of science as objective and value-neutral makes policy content based on scientific discourse to be regarded as common sense, positioning it beyond the political debate (Shore, 2011; Zinn, 2011).

Discussing technocratic visions of wave energy futures that persist in policy documents, elsewhere (Simakova and Iskandarova, 2013) we suggested that such visions are largely informed by commodification and technologising of wave,[78] which would allegedly lead to 'unlocking the potential' of wave energy. Moreover, it is suggested that in this sense policy can also be seen as a humanist pursuit to exercise human powers over nature (ibid.).[79]

When it becomes part of technological change, wave is used as a resource to trigger the complex initiative to start funding, university-industry relations, and get public consent on appropriation of natural resources for technological projects (ibid.).

In documents, policy is partially constructed as a response to the needs of industry which is presented as immature. In visions of industry development future remains uncertain, and depends on public-private funding. The rhetoric of uncertainty is

[78] I will take a closer look at the scientific discourse of wave in chapter 7 whereby waves are widely regarded as a 'natural' phenomenon, or as a natural mechanism for the movement of energy. I will explore how scientists approach it and construct waves as an object of study and research for renewable energy ('Wave in scientific discourse').

[79] The workshop *Varieties of Posthumanism: Policy as Practice and Performance*, University of Exeter, March 6th 2013.

underpinned by the recognition of variability of available technological options and designs, and the difficulty to make priorities in assigning such funding. Policy 'hears' industry voices and is capable to identify and engage with industry needs, with various degrees of success. It is admitted that the appropriate regulatory framework is necessary and funding for the sector needs to be in place (MEAP 2010). Nevertheless, critique can be heard that policy is slow and is not recognising the reality of developing energy areas. It is claimed that radical changes to renewable energy policy are required, but they must be institutionally appropriate to the UK (Pollitt, 2010).

Recognition of the marine industry as being capable of making a significant contribution towards a low-carbon economy is underpinned by strategic planning and support mechanisms introduced by the UK government and devolved administrations in recent years, which will be discussed in the next section.

5.2.2. Policy mechanisms and instruments to support renewable energy in the UK

Policy and strategy in the field of renewable energy (including marine energy) are underpinned by legislative acts and regulations[80] which introduce various mechanisms for policy goals implementation and measures which are perceived as able to encourage deployment of renewable energy in the UK. In this section I will explore in more detail those support mechanisms, instruments and initiatives which were in place at the time of data collection and were perceived as relevant to wave energy and to my case study.

5.2.2.1. Financial mechanisms for renewable energy

Policy documents and legislation introducing support mechanisms and schemes (mostly financial) for wave energy sector in the UK are considered as the most impactful.

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[80] Specific maritime regulations (in regard to environment protection, planning or ownership) relevant to the case study will not be considered here as being partly covered in the previous chapter 'Emergence of a macro-actor: a possible history of Wave Hub' and partly discussed in the next section of the current chapter.

The dominant concept employed in the UK policy discourse is based on the idea of independently regulated markets, with the 'right interventions' to correct specific market failures. Nevertheless, the market-oriented theme in the policy discourse proved to be controversial. This approach is criticised as being inefficient for regulation of immature industries which cannot compete with well-developed commercialised sectors and technologies. Some believe that a traditional for UK policy commitment to market mechanisms (so-called 'financial capital') posed certain challenges to renewables innovation in the UK, including the marine energy sector (Winskel et al, 2006).

The UK was an early adopter of financial mechanisms to support deployment of renewable energy. The Non-Fossil Fuel Obligation (NFFO) was adopted in 1990 with the aim of making renewable energy projects commercially viable but to incentivise growth at lower cost through application of competition to the winning contracts (Woodman and Mitchell, 2011). Later, the Renewables Obligation (RO) replaced the NFFO with another competitive subsidy system rooted in cost minimisation but which increasingly looks to have been misjudged (Mitchell, Bauknecht and Connor, 2006; IEA 2007).

The Renewables Obligation (RO)[81] is currently the main support mechanism in place for large scale renewable electricity technologies, though it is due to be replaced by Contracts for Difference – Feed-in Tariffs (CfD FiT) from 2013.[82] The Renewables Obligation is an obligation on electricity suppliers to supply a specific and growing proportion of electricity from eligible renewable sources in order to increase the level of renewable generating capacity and so contribute to our climate change targets

[81] The Renewables Obligation Order 2009, SI 2009/785. The Renewables Obligation (Scotland) Order 2009, SI 2009/140. The Renewables Obligation (Scotland) Amendment Order 2009, SI 2009/276.

[82] A Feed-in Tariff system was introduced in the UK in April 2010 to support renewable energy technologies up to 5MW capacity, primarily aimed at stimulating smaller-scale technology; it does not help in developing wave energy since this is not an eligible technology. Wave energy remains eligible under the RO but the low level of deployed wave capacity means it does not really receive support this way. It is suggested that the RO is not really an appropriate support mechanism for a technology which is not approaching commercialisation (Foxon et al., 2005). The contracts for Difference scheme, developed through the Electricity Market Reform, was introduced in the Energy Bill 2012-2013 to support renewable and other low carbon technologies. The CfD FiT is seen as the preferred instrument by the Government to deliver investment in low-carbon technology compared to alternatives, including a premium Feed-in Tariff. CfD are presented as long-term contracts to provide stable and predictable incentives for companies to invest in low-carbon generation.

(DUKES 2010). The RO was introduced in April 2002 with an original end date of March 2027. This was later extended to March 2037 to try to establish the longevity of the programme and thus reduce costs linked to risk within renewable energy development. The intended replacement of the RO with the CfD has led the Government to propose phasing out the RO; eligible new plants will be able to opt for either the CfD or the RO between 2013 and 2017 before the RO closes to newly commissioned plants from April 2017.

What was perceived as problematic for the RO as initially introduced is that in order to minimise cost it was intended to be 'technology blind'. This meant that less commercially mature technologies would only receive the same amount of subsidy and thus investors were incentivised to invest in only the most mature technologies to maximise profit. As a result, the subsidy went to a few technologies and not the full range of renewable energy technologies. Particular shortfalls in technology development were in offshore wind and in biomass, but the initial form of the RO also failed to stimulate wave, tidal and other renewable energy technologies all of which were held to be possible long-term contributors to UK electricity supply and to decarbonising that supply. Foxton et al. (2005) argue convincingly that the mechanism was not well suited to support technologies other than those at a stage approaching commercialisation. This was due to their inability to compete at the same level with more commercial technology but also because deploying unproven technology meant a high degree of risk and thus much higher deployment cost and the certainty provided by the RO did not being to match this.

To address these issues the RO was reviewed and in 2009 was adapted to differentiate levels of support between technologies through a system known as banding; this issues different numbers of Renewables Obligation Certificates per MWh[83] of eligible renewable electricity generated. When banding was introduced, a review of what is known as 'technology specific ROC[84] bands' was scheduled to

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[83] MWh (megawatt hour) is a unit used to indicate power or energy capacity; a megawatt hour is 1 million W·h, (symbols MW·h, MWh)

[84] ROC (pl. ROCs) – Renewable Obligation Certificate. Renewable obligation certificates 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 the electricity. These certificates are effectively

occur every four years, which means that legislation requires carrying out a review of the bands before new bands are set. The ROC bands resulting from the first review were due to be implemented in April 2013.

On 20th October 2012 proposals for the levels of banded support available for renewable electricity generation under the Renewables Obligations for the period 2013-2017 in England and Wales were published, and public consultations were announced (this did not include Scotland and Northern Ireland where separate consultations are to be undertaken on proposals on banded support). The regulations setting the new bands in law were anticipated to take effect on 1 April 2013.[85] The assessed potential impact of revised Renewables Obligation technology bands formed the basis for the proposal, and one of the options suggests extra support for marine energy with 5 ROCs/MWh for marine technologies for capacity up to 30MW per generating station.[86] The Government's explanation for these changes emphasises the need to bring these 'nascent' technologies into mainstream deployment, recognising the current state of the wave energy industry which is not ready for commercial scale deployment, but at the same time seeing significant 'potential' for these technologies to help meet the Government's longer term 'decarbonisation goals'[87]. A review of responses to the proposal illustrates that the so called ROC reform was welcomed and widely supported by the industry and interested stakeholders, including Wave Hub.[88]

The consultations that took place in 2008 and 2011-2012[89] can serve as an illustrative example of a commitment to public engagement and collaborative policy

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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 of the electricity. http://www.buildingforafuture.co.uk/winter06/ROC'S.php

[85] Department of Energy and Climate Change http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/renew_obs/renew_obs.aspx

[86] Potential Impact of Revised Renewables Obligation Technology Bands. A report to the Department of Energy and Climate Change December 2011

[87] Consultation on proposals for the levels of banded support under the Renewables Obligation for the period 2012-17 and the Renewables Obligation Order 2012 // DECC http://www.decc.gov.uk/en/content/cms/consultations/cons_ro_review/cons_ro_review.aspx

[88] Wave Hub welcomes proposed ROC reform. http://www.wavehub.co.uk/news/press-releases/wave-hub-welcomes-proposed-roc-reform/

[89] DECC, 2012. Consultation on proposals for the levels of banded support under the Renewables Obligation for the period 2012-17 and the Renewables Obligation Order 2012.

dialogue, the core element of which is the consultation process with a number of diverse independent stakeholders and interested parties. Consultation with the public became one of the policy requirements in many European countries, and particularly in the UK, and can be viewed as symptomatic of the state of science-society relations (Irwin, 2006). The importance of public trust and the need to take social concerns seriously has become, in Irwin's view, a standard part of the policy repertoire, representing the significant rhetorical shift towards a style of 'scientific governance', based on public dialogue, transparency and democratic engagement. Nevertheless, the critical analysis of the assumptions about greater public consultations over technological and scientific development suggests that the significant changes are unlikely, especially in terms of the practical implementation of over-ambitious political rhetoric, due to 'the structural constrains on the possibilities for scientific citizenship imposed by the institutional framing of the exercise' (ibid., p.301). Until more fundamental changes in institutional practices are made, engagement initiatives will probably be structured in accordance with government institutions' operational assumptions and understandings of the policy process, where the conventional model of 'best expertise', practiced by those institutions, will remain unchallenged (ibid.).

It has been suggested that 'collaborative policy dialogues are typically ad hoc, organized for a particular issue for particular place and time' (Innes and Booher, 2003). This is probably an issue in many jurisdictions and/or often in regard to certain areas of policy-making. Although the politics of public talk is not the focus of this paper,[90] it is worth noting that in the case of renewable energy policy in the UK, the openness for collaboration with the general public can be explained not only by 'democratic' traditions of policy-making in general, but by the state of the policy in the field. As argued earlier, the renewable energy policy in the UK is in a state of flux, the process of policy-shaping is ongoing, which can make it more reflective and open to various inputs. At the same time, one could be sceptical about advertised reform being simply a consequence of publicly stated recommendations. Although the

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BERR, 2008. UK Renewable Energy Strategy Consultation.

[90] The consultations took place after the data collection was accomplished, and the participants did not have a chance to reflect on this matter.

proposals for ROC reform is presented by policy-makers as a decision made on the basis of collaborative dialogue, the rigid institutional framework and legislative requirements created provisional frame, and only opinions on certain aspects of policy in the field (ROC bands) are welcome (in accordance with the legislation requirements to review the ROC bands).

It must be noted, that at the time of my data collection Scotland had the most attractive schemes for the development of marine energy. The revenue support available through the Renewables Obligation (Scotland)[91] was increased to three ROCs per MWh of electricity generated from tidal stream devices and five ROCs per MWh of electricity generated from wave energy devices[92]. The higher level of revenue support in Scotland was welcomed by the industry, as two ROCs were considered as non-sufficient support for developing projects elsewhere in the UK (Renewable UK, 2010a).

5.2.2.2. Additional financial support schemes for the UK wave energy sector

Market-based mechanisms are still perceived by UK policy-makers as the most effective, although recognition of their limitations and a need for special support (focused funding) for industries like wave energy dictated the adoption of special schemes, such as the Marine Renewables Deployment Fund or the Marine Renewable Proving Fund.

The initial idea behind these initiatives, as officially presented, was to encourage the accumulation of manufacturing and operating experience necessary for the continued evolution of marine energy technologies towards eventual commercialisation by enabling the early-stage pre-commercial operation and trials of a number of wave and tidal-stream energy devices. In policy discourse it is recognised that support needs to be appropriate for the stages of technology development (Carbon Trust, 2010; Foxon et al, 2005).

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[91] The Renewables Obligation (Scotland), known as the ROS, is the Scottish Government's main means of increasing renewable electricity generation in Scotland. The ROS works in tandem with identical legislation covering the rest of the UK. http://www.scotland.gov.uk/Topics/Business-Industry/Energy/RenewablesObligation

[92] The Renewables Obligation (Scotland) Order 2009. The Renewables Obligation (Scotland) Amendment Order 2009.

The first scheme, the Marine Renewables Deployment Fund (MRDF), was established by the UK Government in 2004 to support the demonstration of small arrays of pre-commercial wave and tidal energy devices (Renewable UK, 2010). Policy documents suggest the MRDF aimed to 'support innovative and visionary businesses to take first class research and development (on wave and tidal-stream energy technologies) to market' (DTI, 2005).

MRDF had four components: the Wave and Tidal-stream Energy Demonstration Scheme, environmental research, related research and infrastructure support. Wave and Tidal-stream Energy Demonstration Scheme formed the core of MRDF and accounted for £42 million of the MRDF's budget. It was supposed to provide capital grants and revenue support to multi-device early stage commercial generation facilities using technologies that have completed their research and development and are ready to move into a commercial environment[93]. The remaining £8 million of the £50 million fund aimed to support environmental research, related research and infrastructure.

The MRDF was criticised as it never had been accessed by a single device developer until its closure in 2011 (Vantoch-Wood, 2012). The 2010 Marine Renewable Energy State of the Industry Report highlighted two reasons why developers had not been able to access the MRDF to date: first, many developers could not obtain the funding required to install the first full-scale device, and second, marine energy device development is challenging, takes a significant period of time and does not allow the opportunity to prove performance onshore before going offshore (Renewable UK, 2010a).

The failure of MRDF to 'inject funding into industry' (as no projects had succeeded in fulfilling the eligibility criteria – 3 months full-scale device sea trial data[94]) led to

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[93] Department for Business Innovation and Skills (BIS). *Marine Renewables Deployment Fund (MRDF)*. http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/energy/environment/etf/marine/page19419.html

[94] 'The Scheme is intended for technologies that have completed their pre-competitive R&D, have been demonstrated at full scale in a representative range of realistic sea conditions for at least three months continuously (except for planned shutdown) or six months cumulatively in any 12-month

another policy initiative that could bridge the funding gap (the 'valley of death') for wave and tidal-stream energy technologies – the Marine Renewable Proving Fund (MRPF). MRPF was launched in 2009 and managed by the Carbon Trust[95] on behalf of the DECC. The Marine Renewables Proving Fund (MRPF), £22.5 million scheme, aimed to accelerate the leading and most promising marine devices towards the point where they can qualify for the Governments then existing Marine Renewables Deployment Fund (MRDF) support scheme and, ultimately, be deployed at a commercial scale under the standard Renewables Obligation. Up to £6m was available to successful applicants to help meet the capital costs of building and deploying wave and tidal stream prototypes. MRPF was purely capital support providing sixty percent of a developers' first full-scale commercial project costs with the rest to be matched by technology developers and their partners. This scheme was announced to support the most promising wave and tidal devices through the final design stage, construction, deployment and commissioning of full scale prototypes with the aim to getting the most mature projects to the point where they can qualify for MRDF support (Carbon Trust, 2009).

In addition to the UK schemes the Scottish Government created the Wave and Tidal Energy Support Scheme (WATES)[96] and the Wave and Tidal Energy: Research Development and Demonstration Support fund (WATERS)[97] to support the deployment of wave and tidal energy devices. The aim of the former (£13 million) is to provide grants to support the installation and commissioning of pre-commercial

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period, during which designs, performances and costs of your project have been verified and are ready to begin commercial operation thereby reducing the technical risk involved.' (DTI, 2007, p.7)

[95] The Carbon Trust is a world-leading organisation helping businesses, governments and the public sector to accelerate the move to a low carbon economy through carbon reduction, energy-saving strategies and commercialising low carbon technologies. Created in 2001, the Carbon Trust has been active in the marine energy sector since 2003 when funded the European Marine Energy Centre (EMEC) in Orkney.
Carbon Trust. About us. http://www.carbontrust.com/about-us
Carbon Trust. 2009 *Marine Renewables Proving Fund. Unlocking the potential of wave and tidal energy*.
http://webarchive.nationalarchives.gov.uk/20091005215558/http://carbontrust.co.uk/NR/rdonlyres/26433B50-C1CD-4785-8411-4E002A3EDA26/0/901141MarinebrochureSinglepagelayout.pdf

[96] The Scottish Government. *Wave and Tidal Support*. *Introduction*.
http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Energy-sources/19185/20805/WTSupportScheme/WTSupportSchemeIntro

[97] The Scottish Government. *Wave and tidal energy fund*.
http://www.scotland.gov.uk/News/Releases/2010/03/22085856

wave and tidal devices at EMEC; the latter is a £12 million fund, established in 2010, aiming to support the testing of new wave and tidal prototypes in the seas around Scotland.

In 2011 a replacement for MRDF was established – the Low Carbon Fund's Marine Energy Array Demonstrator (MEAD) with budget up to £20 million to support the sector moving from single device prototypes to first arrays of full-scale devices[98]. The (Scottish Government funded) Marine Renewables Commercialisation Fund (MRCF), administered by the Carbon Trust, is an £18 million fund to help to commercialise the marine energy industry in Scotland providing capital support to accelerate the deployment of commercial-scale wave and tidal stream energy arrays in Scottish waters[99].

Another significant scheme providing financial support for development of marine energy technologies came from the Technology Strategy Board (TSB). The TSB is 'an executive non-departmental public body', established by the UK Government in 2007 and sponsored by the Department for Business, Innovation and Skills (BIS); the activities of the Technology Strategy Board are jointly supported and funded by BIS and other government departments, the devolved administrations, regional development agencies and research councils.[100] The role of this body is to promote, support and invest in technology research, development and commercialisation in order to 'stimulate technology-enabled innovation in the areas which offer the greatest scope for boosting UK growth and productivity'[101]. Energy is announced as one of its focus areas. Funding opportunities provided by TSB seemed to be essential for those few device developers who had accessed TSB funding.

To sum up, funding opportunities available for marine wave energy technologies are very limited and not consistent. It is argued that there is a lack of appropriate funding continuity for wave energy developers beyond a certain point; a disjointed support

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[98] DECC. *Marine Energy Array Demonstrator (MEAD) Capital Grant Scheme*. http://www.decc.gov.uk/en/content/cms/meeting_energy/wave_tidal/funding/mead/mead.aspx

[99] Carbon Trust. *Marine Renewables Commercialisation Fund*. http://www.carbontrust.com/client-services/technology/innovation/marine-renewables-commercialisation-fund

[100] Technology Strategy Board. http://www.innovateuk.org/aboutus.ashx

[101] Ibid.

system, whereby both the separate supported actors (e.g. device developers, universities, etc.) and the timeframe of support programmes often do not complement each other, needs to be replaced by a more cohesive and interactive support framework (Vantoch-Wood, 2012).

Government policy in the field of marine energy (the marine support framework at the time of data collection) has often been criticised for creating a so-called 'gating system' (or 'technology gating') (ibid.), providing finance support for the most mature technologies and failing to provide support for others to move to full scale commercial deployment. For example, technology developers with 'ready to go', 'well-progressed'/'well-developed' concepts were seen as a primary target for MRPF scheme (Carbon Trust, 2009). There is a danger for the system 'to lock itself in to an outcome not necessarily superior to alternatives, not easily altered, and not entirely predictable in advance' (Arthur, 1989, p.128). In other words, this situation might lead to 'technology lock-in', when the technology selected by the market under which it is operating would not be the one with the highest development potential (Vantoch-Wood, 2012).

5.2.2.3. Boundary support initiatives

A series of initiatives were developed at the boundary between industry, state and academia. For example, non-financial mechanisms for supporting marine energy in the UK result out of the development of renewable energy policy. Marine test centres are significant policy initiatives that need to be mentioned. The main idea behind is to understand reliability of technologies and to be able to forecast their performance before commercial (full) deployment in tough sea conditions.

Test centres in the UK other than Wave Hub include the National renewable energy centre (NaREC) and European Marine Energy Centre (EMEC). These test centres were built prior to Wave Hub and were operational at the time of data collection[102].

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[102] Falmouth Bay Test Site (FaB Test) is located on the south coast of Cornwall. It was launched when the data collection was completed. The FaB Test is a nursery facility which enables wave energy device developers to test components, concepts or full scale devices in a moderate wave climate with access to nearby port infrastructure. The site offers water depths of 20m-50m and

The first, NaREC, was announced as the UK's national translational research centre for accelerating the deployment of offshore renewables. It consists of open-access test and research facilities. Technical facilities at the centre assist in prototype development and testing of offshore renewable energy technologies (offshore wind, wave and tidal energy generation technologies).

Established in 2003 in Orkney, Scotland, The European Marine Energy Centre (EMEC) Ltd aims to provide developers of both wave and tidal energy converters with 'purpose-built, accredited open-sea testing facilities'. EMEC is described as multi-berth, open sea test facilities for wave and tidal energy converters.

Marine energy infrastructures and testing facilities in the UK like EMEC and Wave Hub are presented in the official discourse as encouraging results of policy in the field aiming to support new renewable energy projects in the UK.

Research in the field of wave and tidal stream energy is carried out at a number of academic institutes and facilities available to support device developers in testing their devices in tanks and at sea (SuperGen UK Centre for Marine Energy Research (UKCMER)[103], the Peninsula Research Institute for Marine Renewable Energy (PRIMaRE)[104]). Research groups focusing on marine renewable energy are presented as centres of excellence delivering world-class research and technology transfer in marine energy. Strong links with test centres are essential for such research initiatives (e.g. PRIMaRE was established in support of Wave Hub). One of the latest initiatives can also be mentioned – the Wave and Tidal Knowledge network,[105] a website to support industry collaboration, which was launched by the Crown Estate in April 2013.

Industry representation also plays a significant role in policy development and implementation. Several industry bodies, such as the Renewable Energy Association (REA), the Marine Renewables Industry Association (MRIA), Subsea UK, and

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seabed types: rock, gravel and sand. http://www.wavehub.co.uk/information-for-developers/falmouth-bay-test-site-fabtest/

[103] http://www.supergen-marine.org.uk/drupal/

[104] http://www.primare.org/

[105] The Crown Estate. Wave and Tidal Knowledge Network. http://www.waveandtidalknowledgenetwork.com/

Renewable UK represent the wave and tidal industry. For example, one of the leading renewable energy trade associations in the UK, Renewable UK, identifies itself as the trade and professional body for the UK wind and marine renewables industries. The primary purpose, as announced, is to promote the use of wind, wave and tidal power in and around the UK, acting as a forum for the UK wind, wave and tidal industries and as a lobbying group to promote wind energy and marine renewables to government, industry, the media and the public. The reports prepared by industry bodies (e.g. Renewable UK (2010)) are another example of the discourse formed around renewable energy and a valuable addition to government’s reports and other policy documents. Containing policy assessment, they aim to perform as representing the views of one of the powerful stakeholders – the renewable energy industry in the UK.

To sum up, the state of renewable energy policy and marine energy in the UK, including the political agenda, the process of policy shaping and the changing of the financial mechanisms, makes the UK renewable energy policy a rich object for analysis. Although only key support mechanisms were considered in the section above, it gives an understanding of a complex support policy landscape in the UK for wave energy.

5.3. Policy in participants’ discourse: revealing critique and antagonism

The story of Wave Hub is permeated by the policy discourse. Different facets of a network, referred to as the renewable energy policy and regulation, are introduced and widely discussed in the interviews. The main themes include the assessment of the political regime in the UK and its comparison with other jurisdictions, the access to financial resources and the financial mechanisms in place, the legal framework (including EU regulatory framework), the competence and roles of national and regional authorities.

The policy theme appeared to be very significant in the participant accounts of Wave Hub (which is perceived as part of a bigger picture). It was brought into focus when discussing various aspects of the project: starting with the very idea of Wave Hub, its funding and governmental support, the change of Treasury guidelines enabling SWRDA to act as a host and to run Wave Hub itself, moving to the discussion about problems and barriers for the project implementation and further operation, speculations about its future and the incentives for device developers willing to deploy their machines at Wave Hub, comparison with EMEC and the policy regime in Scotland, and even talking about the credibility and belief in the project's success.

Renewable energy policy is commonly perceived by my participants as emergent from powerful institutions (associated with the Government or the Government itself), which are making crucial decisions for the industry and that can be spoken about as an object of critique. For instance, participants observed that favourable political regime and an access to financial resources can be the key incentives for companies in terms of choosing a jurisdiction (P1), and participants are calling for the UK Government to work on a 'big strategic level' in regard to marine energy (P5).

Admitting that there had been some progress made in terms of creating the 'right conditions' for the development of wave energy in the last ten years, one of the industry representatives (a device developer, one of the 'front-runners' and a recipient of government funding) believes that to make it worthwhile for the private sector to invest in what appears to be 'more expensive technology' political will is needed to 'put in place the mechanisms, the rewards, the taxation schemes (i.e. policy and market mechanisms) that will reward people sufficiently to invest in renewable technology [wave energy]' (P22).

The critique of the Government and its policy, and in particular the financial resources available for wave energy sector, is one the most discussed themes in the interviews. The comparison with other energy-related technologies, including CCS[106], illustrates the dramatic difference in support and allocation of the resources, in participants' view: 'Billion pounds go into carbon capture and storage, and 100

[106] Carbon capture and storage (CCS) (sometimes carbon capture and sequestration), refers to technology attempting to prevent release of large quantities of CO_2 into the atmosphere from fossil fuel use in power generation and other industries. (Global CCS Institute. *What is CCS?* http://www.globalccsinstitute.com/ccs/what-is-ccs).

millions into all of the renewable! [sic.][107] This message is a bit disheartening! So the amount of Government's investments coming to the industry is smaller than we would like. Why? Because they [wave and tidal] probably do not contribute directly to 2020 targets. You know, wave and tidal will be major players for 2030, 2050 targets.' (P14). A comparison with the Government's spending on nuclear energy also seemed to be frustrating for wave energy stakeholders: 'the Government 'put less than half a million pounds a year into a technology.. that's across all [renewable] technologies. Over 50% of DECC's annual budget goes to nuclear decommissioning, so that is around about two billion pounds per year <...> we are talking about infinitesimally small amount of money which have been given to wave and tidal sector.'(P22)

The representative of the regulatory authorities asserted that '...wave and tidal energy won't form a huge element of that 2020 target, it's still at the early stage of development, it's unlikely that there will be really significant levels of wave and tidal energy deployed by 2020.' (P11) Explaining the situation with the limits of the budget, the participants emphasised the need for prioritising and for effective 'portfolio'. According to one of the Governmental officials, at this stage the focus is on offshore wind, as this source of renewable energy is seen as the biggest contributor towards achieving 2020 targets, although the balance is vital with a longer term view of not focusing on one technology ('we see wave and tidal as being sort of a follow-on to offshore wind'). It was clearly stated, that there is an aspiration and expectations for commercial deployment of marine energy for the period from 2020 through to 2050 (mostly due to challenging carbon reduction targets of 80% by 2050), although moving into a commercial phase for these technologies is still seen as a challenge. Nevertheless, there is a belief that 'particularly it will be a favourable time <...> for wave and tidal energy' (P11). The participants (mainly the representatives of the industry) clearly see the ability to raise financial support as a main factor for the success of wave energy devices.

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[107] Participants operated different numbers in regard to the Government spending on renewable energy.

A common theme that appeared in interviews was a critical assessment of the financial mechanisms in the UK and the regional differentiation. Comparing English regions and Scotland, the participants point to the different degree of political engagement and the ability of Scotland 'to provide enough stimulus that it can add to British policy instruments' (P9). The policy instruments used by the devolved Scottish administration are seen as a serious advantage and a strong commitment to renewable energy (five ROCs in Scotland *vs.* two ROCs in England). Moreover, it is considered as a serious barrier for further development of the Wave Hub project in the South West of England, as '...if you get five ROCs in Scotland and two ROCs down in South West [UK], as a businessman I clearly would know where I am going.' (P15). Moreover, it was argued by one of the device developers based in Scotland that as a direct result of that differentiation 90-95% of commercial development activity within the UK was focused in Scottish waters (P22).

At the time of my study the financial mechanism in the UK was a subject of criticism across different groups of participants (device developers, industry representatives, consultancies, scientists and academics). Some of them envisaged imminent changes in current system, often developing a link between the amount of ROCs and the success of the Wave Hub project: 'They will probably need to do [to change the amount of ROCs] if they are going to make Wave Hub a really compelling case for developers..' (P12); '...we need to readdress the Renewable Obligation Certificates – the market mechanism for encouraging investments in this facility. <...> If you are a device developer, why would you come to England to develop or run a big project?' (P16).

At the same time, despite the main-stream opinion regarding the importance of increasing the number of ROCs for wave energy, a more strategic vision of the situation around market-mechanisms was presented by one of the academics (an energy policy expert). Expressing doubts about the effectiveness of the RO mechanism for the wave energy technologies at first place, the respondent suggested that there was a possibility that 'the industry as an actor might ask for the wrong thing and get it, but end up with a policy which is not effective' (P9). Pointing to the fact that only few device developers had 'devices ready to start generating electricity', the respondent questioned the value of 5 ROCs, that could be eventually granted by the Government which would know that virtually no one would ever use them, since the installed capacity of wave by 2017 would be negligible.

Those of my respondents who position themselves as experts in energy policy also discussed in more detail other policy instruments and funding opportunities, mentioning, in particular, MRDF and MRPF. The main critique was the same as in literature – device developers could not access MRDF funds due to its requirements (a wave energy device must undergo three month full-scale sea trial to qualify for funding). (P9)

The important characteristic of an efficient policy design, in experts' view, is a 'continuum of policy instruments' that must ensure a smooth pathway which would remove barriers (planning, opposition, technical, market) and work to assist deployment of wave energy devices. This means different policy instruments at different stages of technology progression: an 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.

As analysis of my data shows, indirect support for Wave Hub is provided by the Government and regional authorities (i.e. publicly funded grants). 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, in cooperation with regional authorities[108] 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)[109]. In total, three projects – the first potential customers for Wave Hub – have received this type of funding to date. As

[108] The Wave and Tidal Stream Energy Technologies: Reducing Costs and Improving Performance funding competition was managed by the Technology Strategy Board in partnership with the South West Regional Development Agency (SWRDA).

[109] Technology Strategy Board, 2010. *Driving Innovation*. Press Release. http://www.innovateuk.org/_assets/pdf/press-releases/press%20release%20wave%20and%20tidal%2023july10%20final.pdf

one of the participants admitted, '...TSB makes it clear that it wants a UK location – EMEC 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. <...> The fact that Wave Hub is there and the fact that SWRDA wanted to get along, I think, put us in advantage in the TSB competition. And I am very happy to be using it.' (P14).

Another initiative, introduced by the Government, although not directly addressing renewable energy sector, is criticised as undermining the ability of English regions to provide a support for renewable energy – the abolition of the Regional Development Agencies.[110] It is argued that the RDAs were big enough to think about projects like Wave Hub, as they could take a view for a whole region, making decisions beneficial for the region as whole, when new 'local partnership enterprises', working at the county level, would not have enough resources for renewable energy projects and that strategic view (P5, P9).

Many interviewees articulated their concern that the policy regime in the UK is too complicated and not sufficiently clear. Consequently, the complexity of regulatory decision-making is another concern for the industry beside finance. For example, one respondent, assessing the attractiveness of markets for his company (as a company with global view), put the UK policy in comparison with other world policies: 'I would say the kind of policy, the clarity of the policy in the long term and the difficulty engaging with the Government is no better than anywhere else in the world, arguably worse.'

The participants see it as a challenge to deal with contemporary policy in the UK, pointing to the interdependence of the renewable energy policy with the 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 in Wave Hub. And a lot of that is to do with

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[110] In June 2010 the UK government announced plans to abolish the Regional Development Agencies (RDAs) with effect from the end of March 2012. Economic development and regeneration will in future be led by Local Enterprise Partnerships and other successor bodies. http://www.englandsrdas.com/

the national.. you know, policies on innovation, energy economic development, all come together or all don't if the case may be. If you are looking at trying to engage with the UK Government across all of those sort of policy spheres, then I can spend my entire working week or year just doing that, and that probably would mean talking to the finance community or potential fabrication partners or utility companies or any other people I need talk to.. So the money is only a part.. the money is only a half a game, the other is how it's easy to get it. And in the UK it's not that.'

Pointing out the human factor in relation to regulatory decision-making, one of the interviewees suggested that '..actually the most difficult thing for a small company <...> by far the most difficult, the scarcest thing, is the type of people who've got the right business and commercial and technical skills to develop these projects and engage with governments. That's as valuable as the actual money. <...> 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..' (P12).

The UK regulation itself ('legal framework'), as well as the Governmental bodies responsible for its delivering and effective implementation, formed a significant part of the discourses I studied. Mostly discussed in light of the difficulties experienced during the consenting process, the UK law ('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 to comply with, such as the Electricity Act, the Coastal Protection Act, the Food and Environmental Protection Act, the Town and Country Planning Act, as well as the new Marine Coastal and Access Act, the participants pointed to some contradictions that could be found in the legislation at that time: '...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.' (P2) The replacement of part of the old legislation by the Marine Coastal and Access Act[111] was characterised as a step to the 'right direction', which

[111] Marine and Coastal Access Act 2009: 'The Act introduces a new system of marine management. This includes a new marine planning system, which makes provision for a statement of the Government's general policies, and the general policies of each of the devolved administrations, for the marine environment, and also for marine plans which will set out in more detail what is to happen in the different parts of the areas to which they relate. The Act includes provision changing the system

probably could lead to 'one-stop shop' in the future (although raising a concern about such system to be 'vulnerable to abuse', 'not politically accountable', 'not auditable'). (P2)

The characteristics of 'the consenting authorities' and 'the various suppliers and experts who worked for them' were part of the discussion about the UK regulatory system. The support of the Wave Hub scheme in general was accompanied by the concerns of the regulatory bodies about 'all the little details', which created, in participants' views, additional barriers and difficulties for the project's implementation. It was pointed to the complexity of the interrelations between governmental bodies and the consultees and dependency on their advice. A conflict of interests with those who were 'not interested in renewable energy' but provided advice to Marine and Coastguard Agency (e.g. Trinity House[112] and the Chamber of Shipping[113]) created 'a bit of a nervous moment' for those seeking consent for the Wave Hub project. That extra-consciousness and careful attention to all details is explained by the fact that Wave Hub was the first project of this kind and 'no one has done it before', and the fear of making a 'mistake' and to create a precedent for the industry was the main motive. It was suggested that the eventual decision was probably instituted 'for purposes of the greater public good', where the objections might be considered 'overruled' because 'we really need a Wave Hub or nuclear power station or whatever it is that the officer is considering'.

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for licensing the carrying on of activities in the marine environment. It also provides for the designation of conservation zones. It changes the way marine fisheries are managed at a national and a local level and modifies the way licensing, conservation and fisheries rules are enforced. It allows for designation of an Exclusive Economic Zone for the UK, and for the creation of a Welsh Zone in the sea adjacent to Wales. The Act also amends the system for managing migratory and freshwater fish, and enables recreational access to the English and Welsh coast.'

[112] The safety of shipping has been the prime concern for the Corporation of Trinity House since Trinity House was granted a Royal Charter by Henry VIII in 1514. This organisation is the General Lighthouse Authority for England, Wales, the Channel Islands and Gibraltar. Their remit is to provide aids to navigation to assist the safe passage of a huge variety of vessels through some of the busiest sea-lanes in the world. Trinity House is also a Deep Sea Pilotage Authority providing expert navigators for ships trading in Northern European waters, and a charitable organisation dedicated to the safety, welfare and training of mariners. (Trinity House. http://www.trinityhouse.co.uk/th/about/index.html).

[113] The Chamber of Shipping is the trade association for the UK shipping industry, working to promote and protect the interests of its members both nationally and internationally.

It is also believed, that this experience, along with the establishment of the Marine Management Organisation, might speed up the process of decision-making for future projects.

The change of a leadership in the UK as a result of the general election in 2010 (a new coalition Government was formed) did not bring significant changes in terms of high level targets and high level aspirations: '..although there are changes in flavour, the overall direction of the department [DECC] remains the same'. (P11)

The theme of the European Union and its policy (or regulatory framework) was raised in interviews with regard to the EU 2020 target[114], the sources of funding for the Wave Hub project (it is also a part of an official discourse and data publicly available), as well as the obligations derived from this support. It is interesting to note, that the potential availability of funding from the EU is seen as a key factor for developing the idea of a big-scale project like Wave Hub: 'Well, even back in 2002 when the idea was conceived.. if European funding had not been potentially available I don't think we would have attempted to start the project..<...> Because the cost was probably more than the money that would had been available either from the region or from the UK Government.. So the fact that Europe could support this kind of project was very important from the beginning... <...> We envisaged that we would apply for European funds.' (P1)

Besides this, EU policy and regulation were brought forward in the discussions around the tendering process and construction of Wave Hub, including various difficulties with this process.

EU and the UK Government support in terms of investment in Wave Hub is seen as a factor which may determine the success of the project: '...there was a massive investment from the government, from Europe.. so in a way I don't think it will fail.. there will be more investments and hopefully there will be more commitments to the Wave Hub and to marine renewable energy.' (P15)

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[114] 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.

The insider's view on the UK policy and regulation in the field of renewable energy was also reflected in the interviews with the representatives of the national and regional authorities. Here the policy theme was discussed in detail (not only in relation to the case study) and was less fragmented. There were no significant contradictions detected in the interviews with different groups of participants regarding their opinions and assessment of the renewable energy policy and regulation.

5.4. Policy as an actant – implications for critical policy analysis?

In this section using the theoretical concepts introduced earlier, I aim to develop my understanding of policy in light of actor-network theory and in relation to a macro-actor (Wave Hub), investigated in the previous chapter.

5.4.1. Reconsidering the notion of policy

For the purpose of this thesis and to answer a research question posed at the beginning of this chapter, it is crucial to decide what is understood by the term 'policy' in this research.

There have been attempts in the literature to gain an explanation for policy and how it happens from an ANT perspective. For example, Freeman (2012) suggests thinking about policy in a wave form. Policy can be presented as the shared understanding of a problem, 'a collective script' which exists only in the extent to which it is called up in the words and actions of those concerned with it (Freeman, 2012, p.13). It appears as an echoing phenomenon that can be compared with waves since, in Freeman's view, it exists only because its elements are moving, and he argues that mobility is its inherent characteristic.

An anthropological approach for interpretative policy analysis suggests that policy is more than 'instrumental governmental tool', as policy can have agency and it changes entering into relations with other actors and institutions (Shore and Wright, 2011, p.20). A concept of policy different from conventional policy science is suggested – an idea of policy as an 'assemblage' rather than a 'discrete thing' (ibid., p.20).

Policy is not a single and coherent thing (phenomenon and subject for analysis). As Law and Moser (2011) 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, 2011, p.17)

In actor-network theory 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, p.522). Following this presupposition, I suggest that policy also can be conceived as a network (or actor-network), in which 'human and non-human elements 'act' upon each other and are mutually formative of each other's contribution to the system' (Galvin, 2009).

It consists of such entities as politicians and bureaucrats, associated research establishments, policy discourse[115] etc. – most of them are heterogeneous and hybrid elements (e.g. human-nonhuman hybrids). Thus the network itself can be described as a 'hybrid imagined in a socially extended state' (Strathern, 1996, p.521). The processes that go on in this network 'can be understood in terms of the interactions between these entities, and the larger hybrid human/nonhuman complexes these interactions produce' (Galvin, 2009, p.4).

It can be noted that networks theoretically are without limit, they are cast as widely as their different elements can be enumerated; the elements that make up a description of a network are the actors in a network (Strathern, 1996). With regard to the renewable energy policy in the UK in its conventional understanding, various

[115] 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, p.44 in Galvin, 2009)

elements constitute this policy and regulatory framework. Across the UK, relevant actors in renewable energy policy include various Government departments (a number of different departments have some responsibility for renewable energy policy and these can often conflict), public officials at national, regional and district levels, budget, spatial planning processes, supply chain availability, network operators and other utilities, a national grid, industry representatives, professionals, academics, probably industrial and domestic consumers to some extent, the wide corpus of documents, and all of them are bound together in this network. Taking a wider view, this network might be imagined as involving other types of policy (e.g. related to innovation, sustainable development, energy economics – and the respondents recognise this in the interviews), international/transnational trends and a political system as a whole. Policy discourse (which acquires a material form in documents and practices) is an important element of this actor-network since the policy network achieves its credibility through discourse.

If one treats policy as an actor-network, it appears as heterogeneous and to some extent ambiguous. Addressing the problem of potentially endless networks, the concept of ownership was suggested as a mechanism for cutting networks and defining the 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), I build my analysis on the suggestion that the boundaries of this actor-network are defined by the participants (negotiated by actors themselves) and depend on what they consider as policy-related issues.

The policy network in this case can be interpreted as the UK renewable energy network, or EU and the UK both incorporated in one, which depends on the perspective, what is brought into focus by the respondents, and the purpose of analysis. In the case of Wave Hub it was defined from the very beginning of the project which policy 'levels' were involved since funding came from both – UK and EU levels, as well as at the regional level through the SWRDA[116]. As a result, a

[116] Wave Hub was funded with £12.5m from the South West RDA, £20m from the Convergence European Regional Development Fund and £9.5m from the UK Government.

partnership was formed between local and national Government and EU. All three 'levels' were clearly acknowledged in the interviews and documentary data.

The policy network configuration changes over time. The rearrangements of governmental departments and redistribution of power between them can serve as an illustrative example: 'It was very clear which department had an interest in Wave Hub – DTI. Then DECC and BIS were created – both have 'very strong interest in Wave Hub', '...us [DECC] very much from energy and climate change side, but BIS from an economic development side supporting the industry' (P11). The view of policy as an evolving thing is also supported by policy experts: 'I would argue that to be successful renewable energy policy has to be a process which implies change.' (P9)

The ANT approach allows us to consider renewable energy policy in the UK 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 (viewed as 'black boxes') (Callon, 1991). Thus, renewable energy policy can be punctualised in other networks being converted in a single actor or node, for example, in the UK energy sector or in overall domestic policy network.

In my interviews the participants provided the descriptions of different connections to the policy network which were viewed as important to them, and there were numerous themes discussed in relation to policy. 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?

The actor-network theory implies a possibility of simultaneous existence of more than one version of an object. A network might have different facets ('faces'). It can be punctualised to a simple node and viewed as a black box (when it is not seen as problematic); it can be unpacked and reveal its complexity and constituent elements. This happens only in interaction with other actor-networks. Such interactions – multifaceted connections reveal the complexity of a network. How one sees those elements and which of them are brought into focus depends on personal individual interaction with the actor-network. For different actors different elements are important, what in turn predetermines different perception of configuration of the actor-network (different interpretations of a network and combination of elements). Why this black box is revealed is important, as the ‘content’ of the black box (actor-network) will also depend on us as viewers. It can be suggested that 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. According to Mol (2003), such multiplicity does not imply fragmentation. It instead reveals the richness of interpretations and connections of a network with other actors shaping the network and moulding its boundaries.

To sum up, in this research by policy I understand a complex relatively stabilised and powerful 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.

5.4.2. Policy and Wave Hub – mutually constitutive networks?

As the analysis of the interviews shows, policy discourse permeates the story of Wave Hub. The Wave Hub project can be viewed as a result of the implementation of contemporary UK (and partly EU) renewable energy policy. The preliminary assumption based on the interview data is that the way the project has been implemented can be seen as an indicator for assessing the renewable energy policy and related regulations, an indicator of their readiness for technical change in the sector.

How to approach the analysis of policy issues? There is a choice for a point of departure. Do policy and regulations represent a stable network themselves whose stability was undermined by new initiatives like Wave Hub and led to certain changes, or is it an unstable, chaotic but flexible thing? What does it represent in the participants’ views?

The general assumption is that in this case study policy cannot be abstracted from Wave Hub – it forms a part of this actor-network and performs a specific function (or multiple functions). Its functionality, in Law’s words, presents and is linked to politics embodied in a network (Law, 2002). Moreover, policy can be seen as an *actant*[117], an active formative element that acts upon other elements in the actor-network.

The ANT approach puts forward the idea that the elements in a network are constituted and shaped by their involvement with each other. Interacting networks can also be simultaneously 'reworked and reshaped' (Law and Callon, 1989).

The analysis of the situation around Wave Hub suggests that policy was ascribed certain impacts, as all those factors also shaped the project – the decision of the Government and EU to provide the financial support for Wave Hub, the lack of supportive financial mechanisms that would encourage developers to come to the South-West, the uncertainty in the sector regarding its future in the UK and the lack of regulation for the consenting process. Such an impact on the Wave Hub project can be interpreted as an influence in a system which is coming from a non-human – albeit human influenced – element: policy. As a result, Wave Hub is caught up in and framed as a policy object.

Policy can become an element of an actor-network in an explicit form (e.g. consenting process) or in a more hidden indirect form as it has an impact on the device developers – economic instruments to stimulate developers to come to England and install at Wave Hub, like ROCs, additional funding and subsidies, incentives for investors etc. (which means that policy can also stand behind other elements of the actor-network and be a part of those actor-networks as well).

Diverse elements that make up a description are considered as actors in a network. From an ANT perspective, Wave Hub as a macro-actor (actor-network) is composed of associated entities, and although these entities, in Callon's words, 'are susceptible to being moulded or shaped', they in turn can transform the actor-network of which they form a part. Wave Hub as an actor-network is composed of series of heterogeneous elements that have been linked to one another for a certain period of

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[117] A similar idea was introduced by Cris Shore and Susan Wright in *Introduction: Conceptualising Policy: technologies of Governance and the Politics of Visibility* (in Shore, C., Wright, S. and Però, D.(eds.) *Policy Worlds: Anthropology and the Analysis of Contemporary Power*, Berghahn Books, New York Oxford, 2011. The authors suggest that 'better way to theorise policies is to think of them as exemplars of what Bruno Latour (1996) terms 'actants' – that is, policies have agency; they shift action; and, like machines, they perform tasks and are endowed with certain competencies' (p.3).

time, and it is able to redefine and transform what it is made of. 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 ANT perspective, only successfully translated actors which were mobilised without contradiction become a background or a context (Law and Callon, 1989). In the case of Wave Hub policy appeared to be an unstable thing and cannot be seen as a monolith background for the project. Policy was significant for a narrative (and actor-network) – it was always a focus of attention for Wave Hub developers and other actors involved in this project. Although at the first glance it seemed that the policy network was mobilised without contradiction being a ‘stable and predictable entity’ (Law and Callon, 1989) and thus providing support for Wave Hub. Later it appeared to be a complex evolving network which affected Wave Hub and processes around it not just at the first stage but continually due to changes and transformations happening in both networks.

The construction of the facility and, lately, its existence influenced the development of the related policy and regulation (as suggested by the respondents, possibly leading to the desirable ‘one-stop shop’ in the future). Relevant regulations have been produced by legislators and changes in existing laws have been made. It illustrates 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). For example, according to the respondents, there was sufficient UK legislation to grant consent to build the project, but there was no legislation to close the area to shipping (safety issues). There were a number of legislative acts – the Electricity Act for connecting to the grid, the Coastal Protection Act (CPA) to do with protecting the coastal environment, Food and Environmental Protection Act (FEPA); onshore planning requirements – the Town and Country Planning Act. This legal framework was referred as complex and sometimes contradictory. Later the changes have been introduced by the regulator as the Marine and Coastal Act replaces CPA and FEPA, which makes it more adjusted for regulating marine energy projects in the future.

The proposed changes introduced to the UK's financial mechanism (5 ROCs instead of 2, in force from 2013) also create an impression that the voices of the industry were heard and were critical to the Government and political decisions made. And as one can see from the interviews, the participants consider these changes as vital for the Wave Hub development.

Thus, the change enhanced the properties of the policy actor-network, as there seemed to be a reverse inverted effect that caused certain changes in policy under the influence of the Wave Hub project and situation around it. In this sense Wave Hub is not just a project that would move wave energy technology forward, but one that probably helped to reveal the weaknesses of renewable energy policy in the UK making them more visible to policy makers and other actors (when anticipated effect was not achieved). The effect on policy, 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 reflects on the Wave Hub case. How can ANT help to explain such 'sluggishness' (inertia, stagnation) of large systems?[118] It is argued that actor-network theory might ease the understanding of these situations and processes – some network are longer due to more elements involved, they are less flexible and responsive to change, and changes in such actor-networks can happen only if the impulse is strong enough to influence the established configuration of a network, as radical changes can affect many elements in actor-network thus the resistance is stronger.

Considering the influence of the policy network we cannot ignore the importance of the political culture and legal tradition. The influence of the judicial system in general which is based on the precedent principle[119] (later cases involving similar issues will

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[118] In ANT literature a few cases were investigated to explain the phenomenon: e.g. why raw onions which upset digestion of large number of people are ubiquitous in restaurants (Star, 1991) or why the Spanish Government were so much committed to sea trade into the Indian Ocean despite huge obstacles (Law, 1987).

[119] In common law legal systems, a precedent or authority is a principle or rule established in a legal case that a court or other judicial body may apply when deciding subsequent cases with similar issues

be based on the first case considered by a court or other judicial body) was significant and determined the process of decision-making for the project. In the case of Wave Hub it was not just SWRDA who had never done such projects before; according to the respondents, nobody has ever done it before – it was a project of a new kind for people involved in its implementation, including the national and regional authorities. This meant that extra precautions had to be made by governmental bodies (e.g. consenting authorities) before granting consents and giving the final approval. As Wave Hub was the first of this kind, later projects which might come up in the future would be able to refer to that very first case, and decisions made in regard to Wave Hub could serve as so called 'road map' for later cases.

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 promissory role of the policy network in relation to Wave Hub, considering the degree of support provided for the project (financial and political) which helped to create an image of Wave Hub as highly desirable, viable and feasible initiative.

It is not only policy that can be an establishing element – the nature (particularly the waves), the wave industry (its existence, ability to bring devices to Wave Hub, its desire to grow and search for optimal solutions, like new infrastructure), the initiator (SWRDA) – all those elements were crucial for Wave Hub as the emerging network and pre-existed it, making the very idea of Wave Hub possible.

Can policy be considered as an extremely powerful element (actor) among them, something 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, which guaranteed the survival of the project (or at

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or facts. Black's Law Dictionary defines 'precedent' as a 'rule of law established for the first time by a court for a particular type of case and thereafter referred to in deciding similar cases.' In other words, precedent can be defined as 'an already decided decision which furnishes the basis for later cases involving similar facts and issues.'

least could do up to a point), a force that pushed it forward along the way and ensuring its legitimacy. It can be called a ‘seed capital’ for Wave Hub as a macro-actor. The idea of considering policy as a base-forming, founding actor can probably provide the ground for a discussion on credibility of the Wave Hub project. As it appears from my data, the rather formal approach to the project was demonstrated from the policy side (national authorities) 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 the project implementations 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 ANT perspective could be that policy is a more complicated, more stabilised (but still evolving) and less flexible network, because it involves more nodes and connections. Once it has its trajectory and branched off (‘gave birth’ to) another dependent actor-network (e.g. Wave Hub), it is unlikely that this new configuration would change radically (or be abandoned), as policy includes the Government, funding bodies, officials, reports and legislation, which means they are supported by plenty other elements, 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, its dependence on Government support and funding limited its ability to manoeuvre and actually to fail or be cancelled.

5.5. Conclusion

In this chapter the main purpose was to investigate an analytical approach to policy as an actant which might have implications for interpretative policy analysis.

For better understanding of the participants’ discourse I started with an overview of the wave energy sector and the state of renewable energy policy in the UK, including the analysis of policy discourse, paying special attention to the mechanisms in place at the time of my data collection. The schematic overview of renewable energy policy evolution in the UK and key mechanisms shows that the renewable energy policy has undergone a series of shifts and illustrates the thesis about policy as an evolving and emerging phenomenon. This also helped to understand stabilisation of renewable energy as a policy category and to consider promissory role of discourse in the construction of Wave Hub as a macro-actor.

As I noted in this chapter, the story of Wave Hub was permeated by policy talk as a prominent theme in the interviews with the project developers and other actors. The analysis of policy and related themes allowed me to formulate an approach to understanding policy as a relatively stabilised and powerful actor-network comprised of heterogeneous elements.

Referring to the debate about context/content dichotomy in STS as analytical basis, I further explored the idea of policy as an actant. The analysis of interaction between policy and Wave Hub revealed the complex constellation of these networks; policy and Wave Hub appeared as mutually constitutive actor-networks. My analysis suggests that being a pre-established, or pre-existing, network, policy became a powerful element in new configuration, a ‘seed capital’ for Wave Hub as a macro-actor, contributing to the project’s legitimacy.

As an element of promissory discourse, policy cannot be abstracted from Wave Hub, as well as Wave Hub became extremely dependent on the policy network. Moreover, Wave Hub can be viewed as a result of implementation of contemporary renewable policy in the UK and serve for assessing the readiness of renewable energy policy and related regulations for technical change. It can be suggested that despite deliberations about its success, this project is viewed as opening 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 is 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 in my case helps to understand the process of adjustment of networks revealing weaknesses and disconnections.

The suggestion about the political nature of the project, its status and dependence on Government support and funding, which could limit its ability to manoeuvre and actually to fail or be cancelled, takes us to the idea of credibility and its construction in case of Wave Hub. This theme will be discussed in the next chapter.

Chapter 6. Constructing credibility: do expectations matter?

'...people do not do the ideal job, but the doable job.

When faced with too many alternatives and

too much information, they satisfice.'

March and Simon (1958) in Bowker and Star (2002)

6.1. Introduction

It was suggested in the previous chapter, that politicisation of Wave Hub (which is framed as a policy object (Webster, 2007)), its status, and dependency on Government's/policy support admittedly limited its ability to manoeuvre and actually to fail or be cancelled. I consider how policy network emerged as a powerful actant, a base-forming, founding actor which guaranteed the survival of the project, a force that pushed it forward along the way and at the same time ensuring its legitimacy. To explore this phenomenon in detail here I will turn to the question of credibility and its construction in regard to the project under study. The question of credibility as a constructed attribute is especially interesting for investigation due to the status of Wave Hub as a national asset, the recognition of its success in the official discourse,[120] a continued political support and the announcement of further developments where Wave Hub is to become the key element of the offer (i.e. South West Marine Energy Park). Although it must be noted that in recent statements the local politicians started expressing more critical view of the Wave Hub project, calling its progress 'lamentable' and expressing concerns about the huge investment that has not yielded any substantial amount of long-term jobs for the local people.[121]

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[120] For example, Wave Hub has been named Sustainable Project of the Year in the business Green Leaders Awards 2011. http://www.wavehub.co.uk/news/press-releases/wave-hub-wins-national-sustainability-award/

[121] BBC News. 20 February 2013. *Cornwall Wave Hub progress 'lamentable'*. http://www.bbc.co.uk/news/uk-england-cornwall-21497516

The question of credibility (or credibility-economy, as suggested by Shapin (1995) in his analysis of credibility concept in the social studies of science), which is central to this chapter, is a complex one. For convenience of data analysis I will split it into two sub-questions: the construction of credibility of Wave Hub as a project or as a macro-actor, and legitimate decision making at different stages of the project development. The first section will explore such important aspects of credibility of Wave Hub (a macro-actor) as the public 'face' and presentation of the project (the 'front stage' (Goffman, 1959)), the official discourse justifying the idea and its implementation; the different meanings attributed to Wave Hub (the perception of Wave Hub by different actors and social groups) and its symbolic capital. It will also allow me to further develop the argument about policy as an actant and to consider its performative role in constructing credibility of the project. The second section will examine the process of decision making throughout the project development, the participants' accounting for 'failures' and 'mistakes', as well as lessons learned out of this process, changes in design and its justification and explanations. Besides, the problem of constructing credibility of Wave Hub turns out to be closely interwoven with the credibility of SWRDA, the wave energy industry, device-developers and their technologies. These themes appeared in the interviews in relation to Wave Hub and are seen by the participants as important for understanding the project's trajectory, the degree of success and future aspirations.

Prior to the data analysis I would like to point to a methodological issue related to historical accuracy and the reliability of data, beginning with the very idea that there is no consistency in the accounts. As it was discussed earlier[122], this raises a question about the limitations of using an actor-network theory approach for the analysis of Wave Hub as a macro-actor. The limits of ANT are that we as analysts have to choose the accounts to describe the trajectory of a project (to build a historical narrative) which leads to the judgements of their relative validity. As such, the ANT approach cannot satisfy thoroughly the purpose of this chapter and needs to be enriched with another approach – discourse analysis, and in particular a version of it that was developed in STS in studies of variability of scientists'

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[122] See Chapter 3 Methodology.

accounts, where the special attention is paid to the variations and inconsistencies in accounts.

In order to explore both the technical and social aspects of the project's development and design, it was necessary to build an awareness of the issues related to the technological side of the project. For this purpose I initially concentrated on the official published data and a few preliminary interviews to gain an idea of what it would take to build an 'overall picture' of the development and an understanding of the most controversial and curious aspects of the design and historical development of the project. This approach allowed me to produce what I termed after Gilbert and Mulkay (1984) a 'possible' history (an outline) of the story and to choose the line of inquiry for semi-structured in-depth interviews. The practical difficulties with the interviews were that the content of the accounts differed to some degree, especially in relation to design development. The problem of resolving differences in the accounts can be aggravated if to concede the analyst's interpretation of the agreement between the accounts and further interpretations (Woolgar, 1976).

The reliance on the participants' 'accounts of accounts' (second-hand accounts) also posed certain challenges, as it can be suggested that the participants imposed their own interpretations and reflection on the information they obtained from various sources (documentary data, discussions with colleagues, mass media etc.) and what they believe 'really happened'. Besides, the sources of the information that were available to them cannot be clearly identified in each case, although the suppositions can be made considering the position and the conjectured access to data of each participant.

Following Woolgar's (1976) suggestion, instead of searching for the accounts that would display, in the analyst's view, the greatest accuracy, here I will pay attention to the differences between the accounts seeing those differences as data in themselves and will try to understand what stands behind such 'inaccuracy' or 'distortion'.

It was not particularly difficult to discern a straightforward sequence of events (chronology of events) based on the participants' accounts despite some variations in regard to the explanations of the events and their meaning, but that is not my main objective. Rather, I would like to explore those variations using a so-called ‘working accounts’ (Woolgar, 1976) of the project development and design based on the interviews with the participants centrally involved in the project development or having direct access to the project documentation.

6.2. Constructing credibility of a macro-actor

6.2.1. Justification, argumentation and ambitions

Earlier in this thesis the history of the Wave Hub project was explored in detail – from the development of the idea to the actual construction of the facility. The participants’ accounts explaining the factors that led to the decision to focus on wave energy were presented and analysed from the actor-network theory perspective. It was shown how the process of translation, that plays an important role in construction of the credibility of Wave Hub, was accomplished through enrolling a variety of material and nonmaterial actants including policy network, thus helping to produce a credible narrative sustaining Wave Hub as a viable socio-technical project. Here I choose and pay special attention to those fragments of data which serve the purpose of building the credibility of the project by justifying and arguing for it being a success or questioning it. This will help to explore how credibility is construed in the case of Wave Hub, to what extent the distinctive features of the project are the means for constructing credible claims, and how reliable and persuasive the rhetoric used to communicate the case is.

Taking constructivism as a conceptual framework for this research, as developed in previous chapters, my approach is based on the perception of credibility as a constructed attribute (or attributed trait), one that is being negotiated and continuously constructed (mainly through the claims of those who deliver the project) and deconstructed throughout the history of the project. It can be understood as a perceived trustworthiness, since in its literal meaning credibility is defined as a quality of being trusted and believed in, being convincing or believable[123]. It includes

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[123] See, for example, Oxford Dictionaries http://oxforddictionaries.com/definition/english/credibility

the perception of management's competence, as credibility of the project is extended to those who implement it and communicate it to the 'outside' world; this, in turn, can affect their reputation.

Discussing the methodological principle for accessing credibility (credibility constructs), Shapin (1995) suggests that 'there is no limit to the considerations that might be relevant to securing credibility, and, therefore, no limit to the considerations to which the analyst of science might give attention <...> any aspect of the scene in which credibility is accomplished may prove to be relevant' (Shapin, 1995, p.260). In his opinion, credibility-predicaments can vary according to the nature of the claims; the relationship between who claims and who is meant to believe are also important (ibid.). For Shapin there is no 'a theory' of how credibility is achieved. For explaining credibility he suggests to specify what the object is and to whom these descriptions and explanations are addressed (ibid.).

The key feature of credibility of Wave Hub as a construct is the other's perception of its trustworthiness and the competence of those who deliver the project. A creation of an intended impression by the means of sending a 'message' (i.e. communicating certain information) to the targeted audience can be seen as the way to gain credit for Wave Hub as a macro-actor and for its management. This process is reflected in the relationship between both sides – those who send a message ('claimants') and those who receive it. Whether declared qualities and features of the project are believable, significantly depends on the expectations and readiness of the audience to perceive the message sent to them. The response is also important and demonstrates how the audience, consisted of different social groups, evaluates the credibility of the claims and whether it perceives them as trustworthy.

The feature of credibility of the Wave Hub project is that in this case credibility can be understood as a complex multidimensional construct. Moreover, it is a sociotechnical construct. SWRDA has to target different groups and send a 'message' to the diverse audience emphasising different aspects. Wave Hub must be seen as credible in order to attract device developers, to justify the rationale behind the project and its economic value to funding bodies, to prove its economic and environmental benefits to the general public and especially to the local population as well as technical capability and feasibility, to prove the competence of SWRDA, etc.

The concept of credibility builds the groundwork for investigating (approaching a discussion of) the success or failure of the project. The evaluation of the project by different groups of participants can help to construct or deconstruct credibility of the claims about the project's legitimacy and success. If successful, it forms a favourable attitude towards Wave Hub and creates certainty around the project in the sense that it is perceived as a doable endeavour.

Here I will analyse not only the content of the claims, but although how these claims are shaped and which forms they take (e.g. official discourse or publications in press). The form is especially important when the analysis is concerned with the visual representations that support the claims.[124]

It was shown in the previous chapters that Wave Hub was a controversial project, experienced a number of delays and pitfalls. Despite that, it is widely recognised as successful (my participants presented Wave Hub as being variously successful according to different sets of criteria), and that was clearly emphasised by the Government's representative: '...Considering how novel this process was, no one has done it before.. that was pretty well.. it's not surprising that there are some hiccups along the way, but *it's clearly been a success.* And I know that a lot of people who are looking at Wave Hub type projects in other countries and now looking at them as being the people to come to for advice.' (P11) The national sustainability award 2011 further recognises its success and its prospective role in building a sustainable and prosperous low carbon economy.[125] Thus, the question arises how the recognition of the project is constructed, what argumentation is used and what is the reasoning behind it.

[124] The visualisation of the Wave Hub project is also a subject of the analysis in this chapter.

[125] Wave Hub, the offshore marine energy project in Cornwall, has been named Sustainable Project of the Year in the business Green Leaders Awards 2011. http://www.wavehub.co.uk/news/press-releases/wave-hub-wins-national-sustainability-award/

The reasoning behind the idea of developing a wave energy project was explored briefly studying what I described as a possible history of Wave Hub in a chapter ‘Emergence a macro-actor: a possible history of Wave Hub’: the long coastline and marine resources available, existing skills and research capabilities determined the idea of developing a project oriented to the wave energy sector; the existing infrastructure to support marine energy industry such as ports and docks, a ship building industry, good transport links and especially an electrical grid were taken into account.

The justification of the decision to target wave energy industry is repeatedly presented in participants’ accounts and serves as an introduction to the story of the project development. The argumentation is also supported by documentary data and pronounced in the various reports and studies: e.g. in support of marine energy (wave and tidal) in Seapower South West Review 2003, and wave energy in particular at the later stages in Wave Hub Technical Feasibility Study 2005, ‘Development of Wave Energy in the South West 2008’. This argumentation has not significantly changed over time. It is worth noting that the reasoning for the project development is not disputed even by those who are the most critical of the project.

The speculation about favourable wave climate was the decisive factor in favour of the wave energy project comparing to other types of renewable energy. When the facility is built, it is still likely to be the most significant ‘selling points’, in the participants’ view, for developers: ‘...So whereas the good point with Wave Hub is that you’ve got enough of the resource to produce power but you don’t have very big waves that you’ve got in the west of Scotland because it’s facing to the Atlantic. So there are selling points for Wave Hub. One is the relatively benign climate, so you’ve got less chances to wrecking your device.. and it’s a real issue of devices working in the sea...’ (P5)

Notably, it was important to present Wave Hub as *infrastructure*. The advantages of Wave Hub as an infrastructure, as a cable connected to the national grid are always emphasised by different groups of participants. The obvious advantage is the connection to the electrical grid: ‘...there is now a link to the grid so you can actually put meter electricity and get paid wherever ROCs there are.’ (P5)

Nevertheless, the participants are still questioning if Wave Hub as a finished built project will attract enough developers and become populated in a short term: '...the interesting part now to me is when the cable is in there how much that will pull people in, because as long as there no cable people just talk 'Yes, this is really good', but if they see the opportunity elsewhere they grab it – they go to Oregon, they go to Portugal or they go to Scotland..wherever if the facilities and the costs are right, and so now when Wave Hub actually has a cable they would be really interested to see how it fits in.' (P5)

The ambitious idea and generous funding allowed talk about 'the mission' of Wave Hub which includes demonstration of commercial viability of wave energy by supporting WEC developers and bridging the so called 'valley of death' between commercial prototypes and full commercial wave farms; making the region attractive for developers to conduct commercial-scale developments; help to develop the emerging UK renewable energy sector and establishing the UK as the world leader in marine energy; contribution to the renewable energy targets.[126]

The direct and indirect benefits for the region are presented by project developers as one of the main concerns for the RDA when elaborating the idea. The belief in a socio-economic revival of the South West is cultivated from the very beginning of the project and is an essential part of the official discourse. The proposed benefits were actively communicated to the public, which helped to create a positive perception of Wave Hub in general, besides some exceptions (e.g. some local companies who were excluded from construction work or a group of fishermen[127] who believe that their interests were violated).

It seems that a discursive relating of Wave Hub to sustainable energy is a crucial factor for building its credibility. The domain of sustainable energy, within which

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[126] Halcrow Group Ltd/SWRDA, 2005. *Wave Hub Technical Feasibility Study. Final Report.* http://www.wavehub.co.uk/wp-content/uploads/2011/06/2005-January-Wave-Hub-Technical-Feasibility-Study-Final-Report.pdf

[127] The situation with fishermen seems to be typical for marine energy projects since the interests of this social group are seen as significantly affected by projects of this kind. See, for example: Orkney fishing industry fears. 7 June 2012. *Oceanology International*, 13-15 March 2012, London, Excel. http://www.oceanologyinternational.com/page.cfm/action=Archive/ContentID=180/EntryID=3266/nocache=07062012

Wave Hub fits, gave Wave Hub its credit from a very early stage. It can be suggested, that credibility of the project was in large based on institutional credibility of renewable energy which is in general not being contested. So the solid ground for constructing credibility of Wave Hub was already there.

The idea of sustainability in its different appearances has become a continuous persistent paradigm that penetrates all spheres of social, political and economic life, and its benefits are not really questioned. It is seen as beneficial for society in the long term, as a desirable (or even essential) path. Persistent propaganda/popularisation of sustainable development ideas, low-carbon economy and climate change scenarios leads to construction of a positive attitude towards sustainable energy and its wide acceptance in society. The idea of sustainable energy, cultivated in society for the last decade, helps to build a solid foundation for any renewable energy development/programme. Consequentially, the positive image is projected on Wave Hub, which is conceived under the so-called ‘umbrella’ of the sustainability concept.[128] Its perception by the general public (who do not have direct interests in the project) was favourable from the beginning. Interestingly, that even within the affected social groups (e.g. surfers) the support of the idea of sustainable energy was presented as the key motive in their acceptance of the Wave Hub project.

As such, in the participants’ views, being in the domain of sustainable energy is the obvious advantage of Wave Hub for the public. The respondents explained that the perception of renewable energy has become more favourable in recent years: ‘...With the environmental debate moving on, perhaps 10-20 years ago, the idea of renewable energy wasn’t something which stirred many passion, because people didn’t believe in global warming and didn’t see the impact on the environment that their energy usage would have. And with better public education, particularly in the last ten years it’s become the new thing that everyone’s talking about, caring about desperately.. and you know, when you have a conference on climate change there is a lot of media interest and so.. now I think the enthusiasm for wind turbines is

[128] See, for example, Lowe (1999), Rip and Voß (2013).

perhaps increasing although resistance against might be dwindling.. Perhaps, there is even more enthusiasm, the whole spectrum of opinion is shifted in favour of renewable energy, so I think you have nothing but praise really from ordinary members of the public, it's only people who are likely to be threaten by like fishermen who objected...' (P2)

As it was explained by the representative of an environmentally conscious surfers' organisation, the reasoning behind their support of the scheme is in large depends of the vision of sustainable energy as beneficial for their community: '...SAS's general view on offshore renewable energy is we're fully supportive of the industry, we feel it can go long way to as setting our greenhouse gas emissions for the country, and that will have a massive positive benefit for the surfing community all around the UK reducing pollution incidents, ensuring that low tide surf sports aren't put at risk from sea level rises and there is also, I mean, we don't know whether patterns themselves will change and swell won't come through the traditional windows and roll across the traditional beaches that they have in the past. So it's very important that we see offshore devices in the right place, in the appropriate places as soon as possible.' (P6)

Besides, in these fragments wave energy is seen as a preferred renewable energy option comparing, for example, with wind energy: '....Public perception was good, because when people think new renewable energy in the South-West, they think onshore wind turbines. And for whatever reason many people in the South-West see wind turbines on rural landscape as being quite ugly. And then that's a commonly held perception. If you then roll up to the same group of people and say 'we're gonna put something that floats on the water ten nautical miles out to sea'..you hardly see this is a total photomontage of it might look like.. 'Yeah!..' far better to have 20 MW array that way than another wind farm because this anti-windfarm feeling.' (P2)

The 'marginal' views, expressing the worries about the cost of such energy for the users, especially in the region 'with a large amount of poverty', were not considered as influential since they did not represent the majority of the public.

One of the crucial arguments in favour of Wave Hub is its complementarity with other elements of the infrastructure in the UK which is seen as beneficial for the industry.

In the official discourse it is argued that the concept of a ‘consented grid connected site for the demonstration of wave energy devices’ was chosen in large due to its proposed contribution as part of a wider UK offer to the marine renewables industry.[129] Right from the beginning, it was seen as complementary to NaREC and EMEC, as the third element of the infrastructure for testing and demonstration of wave energy converters ‘just before their commercialisation’. (P1)

In one of the first documents prepared to justify the Wave Hub project ‘Sea Power South West’ 2003 the intention of the RDA is clearly formulated: ‘...We consider that it is essential for the development of the industry that any approach adopted in the SW should fit with other developments in the sector - for example we *would complement, not compete* with, the European Marine Energy Test Centre (EMEC) in Orkney, and the National Renewable Energy Centre in Northumberland (NaREC).’

A vision of the project as a part of a network (‘central part of the offer’) with NaREC and EMEC became a significant element in constructing a perception of Wave Hub, a distinctive feature of it. The place in this network was allocated for Wave Hub in advance at the early stage of elaborating the concept of the project. Exploitation of the vision of Wave Hub as a part of a bigger picture assumingly gives more weight to the project in the eyes of the Government, the industry, the local authorities and relevant social groups.

The distinctive features of Wave Hub and a specific purpose define its role (‘mission’) in the network. A comparison with EMEC is used by the participants to emphasise the difference between these two projects and to justify credibility of Wave Hub and its ‘uniqueness’: ‘...And it’s much easier in the South West than it is in Scotland, and EMEC, although it appears to offer a very similar type of service they have very, very limited ability to add electricity into the grid cause only a very few people live there and [it’s a] very long way until you reach someone where more power is needed. So we do envisage that these devices might well have been tested as single prototypes at EMEC before they come to Wave Hub. Wave Hub is really that test group of devices not necessarily single device is allowed could do that.. So

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[129] Wave Hub. *Project History*. http://www.wavehub.co.uk/about/project-history/

it was always seen right from the beginning complementary to EMEC and not competing with it. And that remains the case today.' (P1)

The 'unique' nature of the Wave Hub project is constantly emphasised – it is reflected in both documentary data and interviews. It seems to be the most frequently used characteristic for the project pronounced by the participants disregarding their status, representation of a particular group and 'distance' from the project.

Sometimes the 'uniqueness' refers to the whole infrastructure network (network of facilities) in which Wave Hub is seen as a crucial piece of infrastructure: 'The UK is probably one of the best places in the world, if not the best place in the world, to be developing wave and tidal technologies – we've got a lot of people in the UK who've being developing these technologies, we have a very large potential resource, and we also have Wave Hub aligned with EMEC in Orkney and the NaREC (the National Renewable Energy Centre) in the North-East of England – we've got a unique infrastructure for people to be able to develop and test their devices.. So we see Wave Hub as being a central part of the UK's ability to support the development of the sector.. and also to attract activity into the UK.' (P11)

It is also important to note that Wave Hub itself adds value to national and even international programmes creating synergy with the Scottish and North East region initiatives and enhancing credibility of the infrastructure in the UK which can offer facilities for testing and deploying WECs at different stage of development.[130]

Moreover, to support the project and the idea behind it and to make it viable a new initiative was announced and implemented. It creates a vision of Wave Hub as a key element of another macro-actor – an ambitious project to create Marine Energy Park

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[130] A Memorandum of Understanding (MoU) between Pentland Firth and Orkney Waters Marine Energy Park and South West Marine Energy Park was signed at the RenewableUK's annual Wave and Tidal Conference in London. The MoU forms a working partnership that will result in increased collaboration and the sharing of innovative ideas between England and Scotland. Each of these wave and tidal energy parks already provide bases for inward investment in their areas. By joining forces they will exchange information that will help to accelerate the development of marine energy technology from opposite ends of the British Isles. (Renewable UK, 2013).

in the South-West.[131] The UK Government proposals to grant such status to the region was announced after the data collection for this research was fulfilled, and is not reflected in the interviews. Nevertheless, the official information available for the general public provides a clear understanding of the purpose of the energy park and in particular its FaB Test site[132] which is '...a stepping stone to the deployment of arrays of devices at Wave Hub, the world's largest grid-connected wave energy demonstration facility installed 16 kilometres off the north coast of Cornwall in 2010.' It is noteworthy, that this information is published online on the Wave Hub official website. The development of a Marine Energy Park would be likely to add more value and 'weight' to the Wave Hub project, as the idea of developing wave energy that stands behind it gains additional support and materialisation. Similarly, Wave Hub might also add legitimacy to the development of the Marine Energy Park.

The Government was trying to send a clear message about a long-term plan for the development of wave energy in the South-West, starting with the Wave Hub project and elaborating more ambitious plans via Marine Energy Park. It can be suggested that the aim is to give confidence to the wave energy industry (which is still immature) and to potential new entrants to the industry about the availability, possibilities and feasibility of resource exploitation in the South-West.

What follows from my analysis, is that perceptions of credibility available in public discourse increase significantly if an actor is perceived as an element in a chain or a piece in another configuration. In this case its functionality and assignment are aligned with other elements in a network according to the logic[133] attributed to this network. The effect is mutual – as much the place in a network of interrelated

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[131] In January 2012 the South West was named as the UK's first Marine Energy Park, creating a collaborative partnership between commercial and academic organisations, with the aim of speed up the progress of marine power development. (DECC, 2012b).
It is not the only initiative of this kind in the UK. In July 2012 Scotland's first Marine Energy Park, which incorporates European Marine Energy Centre, was launched (the second in the UK). (BBC News. 30 July 2012).

[132] The FaB Test, which is not connected to the grid, gives developers the chance to test devices in a near shore environment that is easily accessible. Tests include investigating structural integrity, response behaviour, mooring/umbilical behaviour, subsea components, monitoring systems and deployment procedures in moderate sea conditions. (Wave Hub. *Information for Developers. Falmouth Bay Test Site (FabTest)* http://www.wavehub.co.uk/information-for-developers/falmouth-bay-test-site-fabtest/).

[133] The logic or schematic views of how commercialisation of wave energy devices is accomplished.

elements supports the credibility of a single actor, this actor performing towards a purpose of a network, with allocated functions, in turn contributes to overall credibility of a network.

In this case study the idea of making the South-West a leader in marine renewable energy drives this further developments, where the projects like marine energy park are seen as a real opportunity for the region to be 'in the vanguard of world development'.

The credibility of Wave Hub, in the Government's view is part of building the credibility of the UK as a 'good' place to develop and test marine energy devices 'to attract activity into the UK' (P11). 'Britain really can rule the waves' ('UK could rule the waves (and tides))[134] – an aspiration presented as a motto for the government when it comes to calling for and justifying more investments and policy support. For the Wave Hub case the degree of political support is high. The fact that the project is funded by the UK Government and European Union makes the offer look viable, deliberate, feasible, and realistic. This support allowed the RDA to implement a very ambitious, large scale project and to make it look viable. Thereby it is possible to talk about the promissory role of a policy network in construction of credible claims around Wave Hub, thus linking my analysis to the body of research in the sociology of expectations in STS.

The discourse about the future of Wave Hub is an essential element of the credibility construct. The expectations are high and closely interlinked with the expectations about the future of wave energy industry. Although plausibility of wave energy technologies is questioned by some of the participants, it was taken for granted by the project developers that there would be devices to install at Wave Hub in approximately five years time.[135]

As this study was conducted when the project development was in process and its future was uncertain, the credibility-economy in the Wave Hub case appears as non-

[134]On 19 February 2012 the Energy and Climate Change Committee published its Eleventh Report of Session 2010-12, *The Future of Marine Renewables in the UK* [HC 1624]. http://www.publications.parliament.uk/pa/cm201213/cmselect/cmenergy/93/9303.htm
[135] See chapter 4 for more detailed discussion.

static: the construction of credibility was not completed; it represents an ongoing process and requires continuous inputs. Constructing credibility is also a way to re-write the project's 'master narrative' (Star, 1999) to some extent and to overcome certain constrains which are the result of the decisions made at the early stage of the development. To adjust to new realities, to increase its potential and attractiveness for other types of renewables, the offer is being modified – Wave Hub is now considered as a possible site for other offshore energy technologies (besides wave energy), such as floating offshore wind turbines.[136]

The discussion around future ownership of Wave Hub during the time of data collection reflects its significance not only for the region but for the country. In the discourse about the ownership the participants referred to the status of Wave Hub as a 'national asset' advocating for the government's control in one form or another as a preferred solution (tying it more firmly with policy network).[137]

The significant aspects of constructing credibility of Wave Hub as a project and as a macro-actor are its public face and (re)presentation, based on the official discourse that accompanied the process of the project development. Using Goffman's (1959) terminology, this can be called a 'front stage' of the project. The publicity for a technological project can be viewed as a way of gaining public support and approval, and as a result be beneficial for the credibility construct (which can also, probably, explain in part an easy access to the field for me as a researcher).

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[136] The UK government-backed Energy Technologies Institute (ETI) is to investigate using Wave Hub, the south west's wave energy test site, for floating offshore wind turbines. The £25 million demonstration project would assess the potential of an offshore wind floating system, which could bring generation costs down and open up new areas of the UK coast to wind generation. <...> Wave Hub is now looking at whether the site would be suitable, with ETI funding a feasibility study by Halcrow, which will be completed this summer. (Energy Efficiency news. 21 February 2012).

[137] At the time of the field work (conducting interviews and data collection) the destiny of Wave Hub had not been decided and its future was not clear to the participants. The SWRDA who were implementing the project was due to be abolished in March 2012 and the participants were aware of this Government's decision. As a result, there were some speculations about the future of this facility and about desired form of ownership ('public ownership' preferred), but at that time the decision had not been made. Eventually, The Department for Business Innovation and Skills (BIS) took over ownership of the Wave Hub asset from the South West Regional Development Agency (RDA) on the 1 January 2012. To manage the day-to-day operation of the testing facility on its behalf, BIS has set up a stand-alone operating company, Wave Hub Limited, which is based in Hayle, Cornwall.

The involvement of media resources and wide coverage of the project in local and national press, along with presentations and lectures that target specific audiences, e.g. academics or industrialists, plays a crucial role for the project's publicity representing the official discourse which was explored here. But it is no less important to understand what kind of response they received and how the credibility claims were perceived by the audience. In the next section I will explore in more detail what Wave Hub means to different actors and how some of its qualities are perceived and assessed.

6.2.2. Representation, meanings and symbolic capital of Wave Hub

To be able to assess the credibility-economy built around Wave Hub, it is useful to understand if the credibility construct has achieved its goal and if the claims about project's innovation nature, success and potential are perceived as true and realistic. For this purpose, it is necessary to analyse how the participants see Wave Hub and how they perceive its qualities (e.g. an innovative character of the project), their responses to the claims put forward by the project developers. In this section I aim to explore different meanings attributed to Wave Hub by different stakeholders, the perception of the qualities attributed to the project and their correlation with the very concept behind the notion 'Wave Hub'.

A construction of a complex and fragile network cutting across the boundaries of organisations and professions leads to variations in interpretations and perceptions of Wave Hub, as well as to variations in evaluation of its success. The empirical materials show that the main 'vector of credibility' (Shapin, 1995, p.269) for Wave Hub is its public credibility. Thus, the public face of the project and its perception by different actors are particularly important. The public face of this actor-network (macro-actor) was constituted by the official representation of the project, including mass media and online resources (e.g. the official website), which are most visible to the general public.

The description of the Wave Hub project on the official website can provide an understanding of what the most important features of the project in the official version are. Namely, on the title page of the official website it is described as a 'grid-connected offshore facility in South West England for the large scale testing of technologies that generate electricity from the power of the waves'[138]. Further in more detailed explanation the notion of 'shared offshore infrastructure' appears along with a specified purpose – 'the demonstration and proving of arrays of wave energy generation devices';[139] additional information is provided about the technical characteristics of the facility. In technical reports (e.g. Technical Feasibility Study), although starting with a general idea of 'an exciting opportunity' that can help the UK to remain a leader in developing wave energy, the Wave Hub concept is explained in 'simple terms' and reduced to 'an offshore electrical 'socket' connecting wave energy converters (WECs) to the national grid'; nevertheless, it also mentions a site with a 'fully monitored wave climate and with a simplified route to permitting and consenting'.[140]

The first feature of the development that can be drawn from the official statements is its purpose, which is defined as testing, demonstration and proving of arrays of wave energy devices. Notably, most of the respondents started the interviews with a reference to the official formal description of the project and its purpose (but only a few added a 'commercialisation of devices' as one of the objectives for Wave Hub). The participants consider testing of devices as a correct behaviour, as an intrinsic, integral part of the successful development of technical artefacts – wave energy converters in this case. This stage is dictated by techno-logic, seen as obligatory and cannot be skipped. For Wave Hub the idea of testing is sometimes specified as 'demonstration and proving'. The explanation is rooted in the initial concept of Wave

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[138] Wave Hub http://www.wavehub.co.uk/

[139] About Wave Hub. http://www.wavehub.co.uk/about/

'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. Wave Hub can readily be upgraded for up to 50MW of generating capacity in the future once suitable components for operating the cable at 33kV have been developed.'

[140] Halcrow Group Ltd/SWRDA, 2005. *Wave Hub Technical Feasibility Study. Final Report*, p.1.

Hub as a third and final element in the chain of testing facilities for wave energy converters in the UK (which also includes NaREC and EMEC).

In the general official statements about Wave Hub the notions of 'testing' and 'demonstration and proving' are both used to describe the purpose of the project, and there is no clear divide between them, although the wording 'demonstration and proving' is a preferred phrase used by the participants reflecting the 'real' idea and purpose of Wave Hub. It is understandable because testing is a more general term. In some cases the purpose of testing can be an interim monitoring of progress and implies probation of technological devices, testing of a single prototype etc., avoiding public demonstration, which is not the case with installing devices at Wave Hub.

It is believed that demonstration of the product (WEC) in action, especially in arrays, which means a number of simultaneously working devices, can prove the feasibility of a technological approach adopted by a developer. It is especially important for wave device developers due to a large number of devices under development that have different designs and characteristics. Moreover, demonstration of a technology can be seen as 'a tool to manage and create social links and partnerships... a key element in the processes that bind the making and the marketing of science and technology' (Rosental, 2005). This idea was also incorporated in the Wave Hub concept, as one of the goals was to communicate the information about the existing and proved working devices to investors and other interested groups.

The second important feature of Wave Hub is the nature of the project – in the official and non-official discourse it is called as a 'grid-connected offshore facility', an 'infrastructure'.

As suggested by Star (1999), infrastructure is a relational concept and can mean different things to different people ('One person's infrastructure is another's topic, or difficulty' p.377); it becomes real in relation to organised practices in which it is incorporated. The main elements of infrastructure in its conventional understanding were also suggested in the literature (e.g. Star and Ruhlerder, 1996, Star, 1999), and it would be useful to see if the Wave Hub project incorporates those elements, or if the notion of an infrastructure should be reconsidered in relation to Wave Hub.

When Star and Ruhleder (1996) defined infrastructure, they pointed to the properties such as embeddedness; transparency; reach or scope; learned as part of membership; links with conventions of practice; embodiment of standards; built on an installed base; becomes visible upon breakdown; is fixed in modular increments, not all at once or globally (Star, 1999). If not all of these are applicable in the case of Wave Hub, does it mean that Wave Hub is not an infrastructure in the sense we usually understand this term (e.g. railways, electricity or water supply systems)?

Some of the properties typical for infrastructure can be found in the Wave Hub project. In terms of embeddedness, it would be fair to say that Wave Hub is 'sunk into and inside other structures, social arrangements, and technologies' (ibid., p.381), being conceived as an element in the chain, i.e. complementary with NaREC and EMEC, and for particular type of technology (wave energy devices). The electrical grid is another infrastructure in which Wave Hub is embedded (physically), and as the history of the project shows, it required certain efforts to adjust the development to the existing grid (e.g. the voltage and as a result the size of the cable were a source of concern). This also represents links with conventions of practice by means of which infrastructure is shaped, and the embodiment of standards, such as voltage in the electrical grid ('plugging into other infrastructures and tools in a standardized fashion') (ibid.). The installed base on which infrastructure rests is also partly there in the Wave Hub case – a decommissioned power station site in Hayle and thus a connection to the grid, from which it 'inherits strengths and limitations' (ibid., p.382).

What seems to be an important characteristic is that Wave Hub can support certain activities enabling its users to do particular things and perform tasks. The suggestion that Wave Hub produces integrations and exclusions configuring actual users, also adds to the perception of the facility as infrastructure. As was discussed earlier in this thesis, potential users were explicitly articulated when the project was conceived, and were further specified at the later stages of the project development. They became a part of the socio-technical relations embodied in Wave Hub. In a position of actual users they will become key elements in this network configuration.

It follows from the descriptions of Wave Hub in the official discourse and some interviews, it is claimed to be an innovative project, 'a novel system which will provide the electrical infrastructure to support developers of Wave Energy Converter devices'[141] and this is an ambitious claim. Probably it is in part because the interest in such claims would be high. Using Shapin's (1995) terminology, the project developers, making such ambitious claims, are taking a 'credibility risk' and it allows them to 'bid for rich credibility-rewards' (ibid., p.265). Discussing 'the moral economy of risks and rewards', Shapin refers to Pinch's (1985) work about solar neutrino scientists and scientific observation, where externality and evidential significance of observational reports are analysed. The experimenter's dilemma is represented by a 'tension between the need for profundity and the need for veracity' – the reports of low externality correspond to maximum veracity but likely to be trivial, while those of high externality corresponds to maximum theoretical significance and likely to be profound but risky (Pinch, 1985, p.24). Shapin (1995) suggests, that in such cases credibility can arise in part 'from actors' *judgements* of risk and rewards, and from actors' beliefs about the credibility-economy into which claims will enter' (Shapin, 1995, p.266)

It is important for the participants and was always emphasised that Wave Hub is the first project for testing wave energy devices in arrays ('there are a few other wave site projects on offer but they are a long way behind this' (P4)). Nevertheless, the majority of them agree that in the case of Wave Hub the claims about the innovative nature of the project are less relevant to the technological side, but rather to the very 'idea' of Wave Hub – testing and proving of wave energy devices in arrays.

The physical characteristics persistent in the official descriptions are also important giving a notion of scale and capacity of the project by means of various measurements (e.g. km, kV, tonne) and simplistic explanations ('an offshore electric socket').

The participants often refer to the official descriptions of the project as a preamble to their own stories. Nevertheless, the different positions in relation to the development,

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[141] Execute Phase Design Basis by JP Kenny.

various expert status and professional affiliations, as well as the degree and the way of involvement affect the vision of Wave Hub and its key features. The evaluation of its success also differs significantly among the respondents depending on the angle from which the development is being assessed.

The abstract meanings associated with the physical or concrete characteristics of the development can be referred to as symbolic (McLachlan, 2009). The symbolic interpretations of technology and place (a location with ‘meaning’) can be multiple and potentially conflicting (ibid.).

Assuming that relevant social groups (Pinch and Bijker, 1984) can attribute different meanings to a technology or an artefact, it would be useful to explore what ‘Wave Hub’ means to different stakeholders in order to understand the various facets of Wave Hub as a macro-actor.[142]

As a physical object, is it a subsea cable with a socket and grid connection? Or should it be understood in operational sense, i.e. with the devices attached rather than the hub or ‘socket’ on its own? Or is it an innovative idea that had been implemented as a project and includes processes and related activities such as design, construction, consenting process etc., or is it an opportunity to get economic benefits, e.g. for the industry, contractors, fishermen, or an opportunity to implement ambitious and costly research projects and generate knowledge, e.g. for scientists and researchers, or may be a national asset and a symbol of environmentally friendly South West Regional Development Agency that helps building a positive image of the South-West and the participants involved in the project? All those varying perceptions of Wave Hub are not contested and do not challenge the official version. Quite the contrary, they enrich the predominant meaning and show that the perception of a project can be a perspective relational thing depending on those who are involved in interaction or provide interpretations. Moreover, they are equally legitimate. It leads to the assumption that Wave Hub as a macro-actor has a variety of possible boundaries.

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[142] It corresponds to what Pinch and Bijker call ‘interpretative flexibility’ (Pinch and Bijker, 1989).

To what extent does it matter when the participants describe Wave Hub? From the analytical point of view, it is important not only in terms of assessing credibility of the project, but also as a way of understanding the different realities enacted simultaneously around Wave Hub that reveal the different facets of the actor-network. In line with the approach adopted in STS, technologies and their impacts can be experienced and defined in multiple ways (McLachlan, 2009). The stakeholders define a particular technology in response to the relationships that the development represents to them (ibid., p.5345). The participants, presenting their understanding and relations with Wave Hub, highlight particular features which seem to be important in their opinion. Exploring varying descriptions of the project can help to define the setting, in which some of them work or operate, as well as their expertise and self positioning in relation to the project and other stakeholders.

The specificity of the Wave Hub case is that the prevailing and most common description of the project is based on its understanding in a technocratic environment, where technology is seen as the only solution to all problems. The view is shared by those who were delivering the project, defining its destiny; it also became the basis for technology assessment in term of its possible impact (e.g. environmental impact). This understanding of the technological project comes along with the perception of Wave Hub as an industrial restructuring project that provides local benefits. For some of my participants, the dependence of Wave Hub on industry growth and device developers, as well as envisaged prosperity for the South-West, are the factors that make it more difficult to decide upon the project's credibility and success – it becomes a quite fragile construct and its success to be judged in a long-term perspective rather than immediately after the facility has been built.

Some of my participants questioned the success of Wave Hub discussing what the concept of Wave Hub means and stands for: 'Do you define it as the undersea connection point or do you define it as an active site wherein the Wave Hub is a point for moving the industry forward and helping to establish wave energy converter arrays? The former leads to success as being a cable installed but this is, in my opinion, disingenuous. Also, to what extent does the retreat from the subsea substation idea represent a failure or diminution of the Wave Hub concept, given that it changed the scope of the goals but also what the Wave Hub will be able to support in terms of WEC capacity at the site.'(P9)

Although all different interpretations and abstract meanings associated with Wave Hub can be recognised as variations of symbolism, it becomes especially prominent in relation to the political interpretations suggested for Wave Hub, the attempts to interpret a technical artefact in political language.

This refers to the debate in STS about the political qualities of artefacts ('artefacts have politics' (Winner, 1997)), whereas the opponents of this doctrine argue that it is not analytically fruitful to talk about inscribed values and qualities (Woolgar, 1991; Joerges, 1999). Moreover, it is suggested that the meaning of technology is also socially constructed. As Pinch pointed out, 'technologies carry no intrinsic meanings. Their meanings always to be found amongst social groups who interact with the technology and share a meaning of the technology' (Pinch, 2010, p.79)[143].

While sustainability is often presented as being an inherent property of renewable energy technologies (McLachlan, 2009), I would argue that, as with other qualities ascribed to a technological project, it would be correct to talk about negotiated character of value which is being constructed and attributed to the Wave Hub project.

The analysis of the discourse around Wave Hub shows that this project often plays a representational role: it is used as emblematic for the South-West region, for some of the stakeholders and even for the UK creating an image of the country that supports renewable energy (providing political and financial support) and wants to be an international leader in the field. As such, the technological project is tied up with much wider issues; its symbolical interpretations obtain additional political sense. This allows us to talk about politicisation of Wave Hub.

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[143] See also Pinch and Bijker, 1984; Bijker, 1995.

6.2.3. Visualisation and representation of the Wave Hub project

One of the most effective ways to communicate the idea of the Wave Hub project is by means of visual images. Thus, the visual representation of the project that accompanies the discourse about Wave Hub becomes an important aspect of the credibility construct. Images in science and technology, their emergence and politics have been a focus of research in STS.

Images are often researchers' and engineers' favourite tool in understanding and explaining the objects of their inquiry or expertise. Visual techniques are used to assist in reasoning and justifications. In order to understand the role of visualisation in representation of the project and how the images contribute to validity and credibility of Wave Hub, it is necessary to pay attention to the cognitive and social implications of imagery of the project under investigation, the articulation of graphic representations, in particular, to understand how visual techniques were used to assist in reasoning and justification, how they reflect the theories about its implementation, and convince the audience.

Besides that, more general questions can be asked about the relationship between schematic images (visual representation of the project) and the complex object they represent, what the meaning the images of Wave Hub communicate, and the epistemic status of visual models (i.e. images and technical drawings).

It is widely accepted that organisations' memories are recorded in archives. Therefore, it can be suggested that Wave Hub's memory is also recorded in documentary data and visual images used there. The case of Wave Hub is very rich in images and various graphics. As a result, it is possible, using different sources, to trace the evolution of the idea and the history of the project through the analysis of visual representations of Wave Hub.

Different categories of images can be identified in relation to Wave Hub. Each of them contributes to the credibility of the project and works for justifying managers' claims, although in different ways. Schematic drawings of the system, artistic visions are the most recognisable representations of Wave Hub; the photographic images of pieces of equipment – static or in the process of installation (e.g. subsea unit, cable);

pictures of people involved and working for the project. The images accompanying Wave Hub are also specific – these are usually images of the sea and waves (powerful, high, dynamic) which also represent the 'potential' for energy extraction. A logotype of Wave Hub is a stylised, conventionalised image of waves which became emblematic for the project. Schematic layouts[144] for technical purposes can be found in relevant documentation, but are not the focus of interest here as they are do not add to the public image of Wave Hub and are to be 'read' and interpreted by experts.

The first images were developed at the very early stage, before the final idea took its shape and prior to the actual construction and existence of the technological object. At the beginning, the simulations and drawings were presenting an absent thing as Wave Hub was a result of engineers' imagination implemented in technical drawings and artistic images. From the material point of view, it was an object from the future, futuristic to a great extent. At this stage, the imagery of the project can be described, paraphrasing Latour's words, as a meeting place for facts and fiction. Bearing a 'propositional content' (ibid.), the images of Wave Hub were initially not only an abstraction but an idealisation of the idea of the project.

As the project proceeded, the images change again as construction work starts. Modification of Wave Hub imagery is a result of a representational relation between images of Wave Hub and a technological system which they represent in a specific way.

From early stage of the development, the visual representations of Wave Hub could play 'the role of making claims' (Perini 2012, p.146). Although being often rather simplistic, the public images of Wave Hub incorporate the schematic representation of the elements which are perceived as significant by the project developers, such as a cable, a hub on the seabed, the devices attached to it by few smaller cables, the substation on the shore on a schematic layouts, and, of course, the sea or marine environment.

[144] See, for instance, example layout of WECs in Wave Hub Final design report. Appendix D – Decommissioning plan.

Visual images help to translate the meaning and communicate the idea of a technological project. Visuals are used on the assumption of quick and positive response in presentation of large scale technological objects. As it was fairly noted, a drift from watching confusing three-dimensional objects, to inspecting two-dimensional images makes a phenomenon less confusing and more understandable (Latour, 1990). A schematic simplification in this case helps to deliver the core idea of the project, the functional principle. The simplification and transparency helps an uninitiated to learn about the project.

As such, imagery of Wave Hub becomes a visual language used to communicate the idea to the public, accompanied by written text to various extents, depending on the purpose and the type of the images.

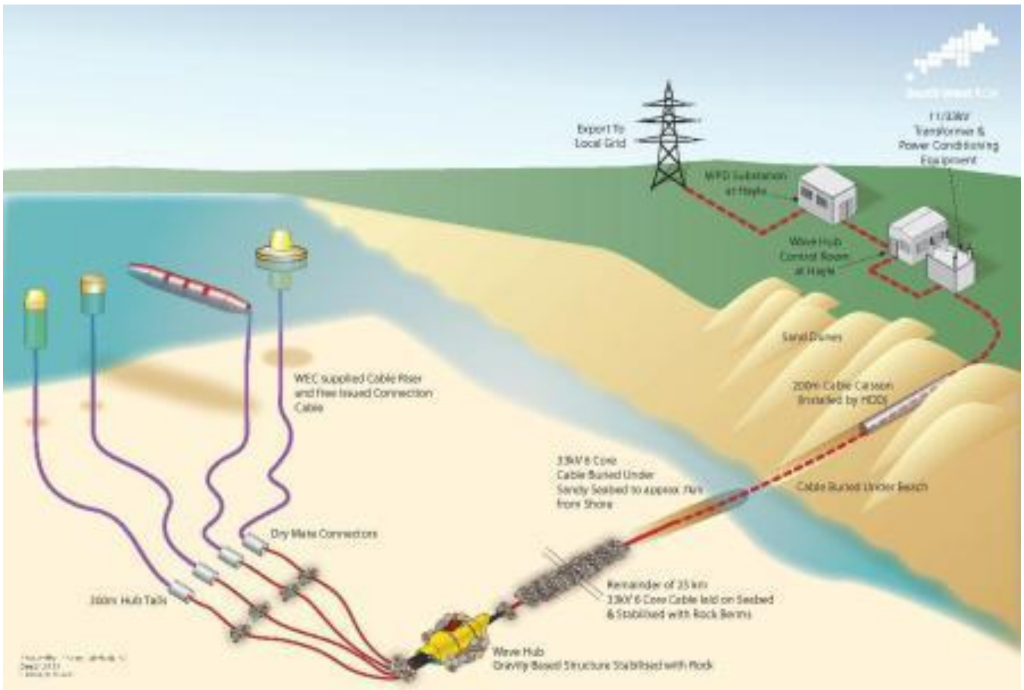
Seeing images of Wave Hub as representing the finalised concentrated 'idea' that was elaborated and got its shape, as a quintessence, helps to understand the reasoning the project developers present that is consistent with their concerns. The important mission of visualisation in case of Wave Hub is to present the project as evident and unproblematic.

It is suggested that maps and visualisations play a crucial role in materialisation of technology, not only showing how the object would look like, but also used as a central instrument of discussion with various stakeholders providing a practical basis for public inquiry (Jolivet and Heiskanen, 2010). They become an indispensible part of the public consultations and the whole consent process. Visual images accompany the discourse around Wave Hub and became indispensible to talks about the project (in documents, presentations, press, and even interviews), as an indispensible part of the public consultations and the whole consent process performing as an evidence and persuading inducing device.

Following Latourian understanding of images as inscriptions (Latour, 1986), it is possible to say that they represent 'the fine edge' of a whole mobilisation process of various allies constituting an actor-network at certain stage of the project development. The presence of WECs on the images implies the involvement of device developers, the shipping routes on the maps suggest the relation with navigation authorities, even the sea on the pictures leads to the involvement of those concerned with the marine environment (scientists and public bodies), apart from all those people and organisations who stand behind the idea ('authors') and those involved in the construction of the depicted technological object. As such, visual representations not only start forming the material side of Wave Hub, but also perform social relations around it.

The status of visual data in the case of Wave Hub is no less significant than textual data (documents, publications, press-releases etc). The imagery of Wave Hub is an indispensible integrated part of the relevant documentation, presentations of the project, official and nonofficial discourse around Wave Hub. It would be productive to suggest that visual representation of the project in the form of images as an artistic vision of Wave Hub and pictures, e.g. photographic images of the hub itself, became symbolic to a certain extent and widely recognisable. Moreover, this case can be illustrative for the production and articulation of graphic and other visual representations of a big technological project as a phenomenal object in professional setting and in public discourse.

Fig. 4. The official representation of Wave Hub (present version)[145]



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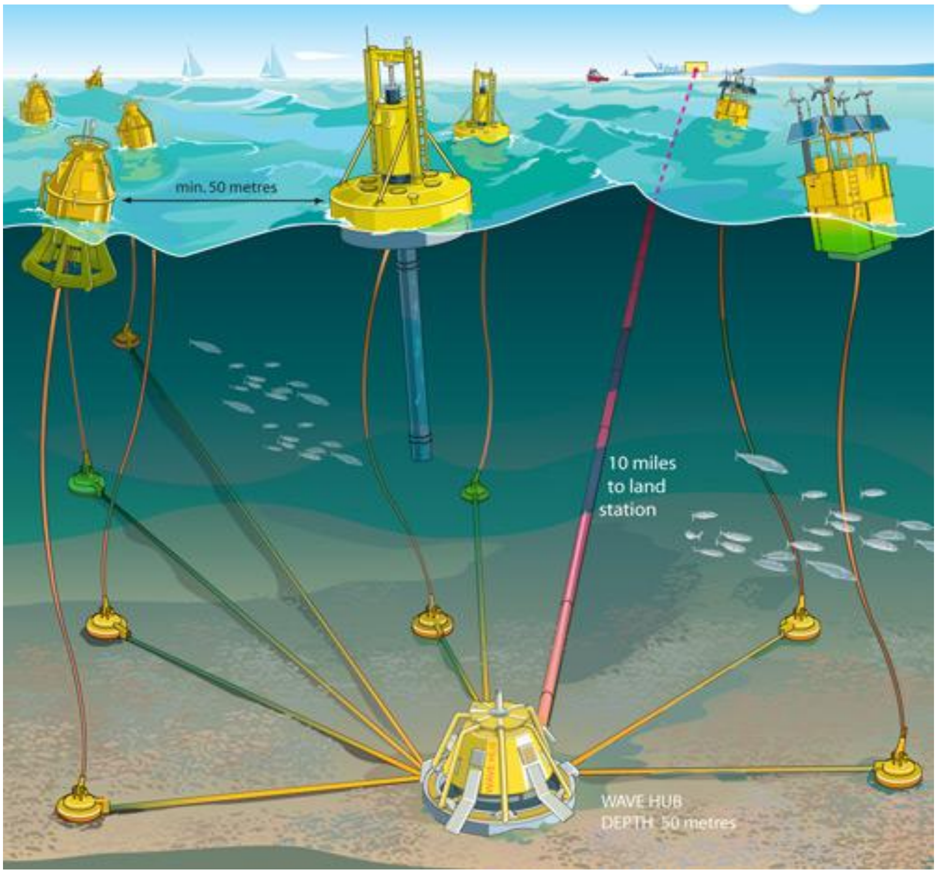
[145] Source: About Wave Hub. http://www.wavehub.co.uk/about/

Fig. 5. Artist's impression for AB Design Group showing the Regional Development Agency's (RDA) major scheme for a Wave Hub in St Ives Bay, Cornwall.[146]



[146] Source: Aylwyn Bowen ideas, design and images.
http://www.aylwyn.co.uk/portfolio/Illustration/wave-hub

6.3. Legitimate decision-making and problems of design

'Despite its name, design is not only plan, plot, intention, prevision, and reification <...> but also emergence, detour, creativity, improvisation, surprise and novelty.'
Storni (2010)

'...it's all about trade of design.'
A representative of an engineering company

6.3.1. Developing a 'credible' design solution

Technical credibility (credibility of proposed technology) plays a particularly prominent role in underwriting the legitimacy and credibility of the entire project. It is directly related to the question of a design of the technology and a search for feasible technical solutions. A development of a credible design solution for Wave Hub became one of the most disputable and controversial aspects of constructing credibility of the project.

To explore the hybrid, relational and emergent nature of a technology, the political and normative dimension of its design, to unpack the design and provide a perspective on design practice in this section I offer a detailed study with the focus on the dynamics and the practical reasoning of those involved in this process and/or providing accounts for it.

The socio-technical settings for design of Wave Hub were analysed earlier exploring the possible history of the project (including the role of non-human actors and different stakeholders). In this section I will pay special attention to the process of elaboration of the design solutions which was discussed in brief in Chapter 4.

Studies of design practices focus on the process of gradual realisation of ideas and engineers intentions, the movements and transformations that lie behind an artefact or technology. As it is suggested by Storni in line with Latour's principle of irreduction, 'the focus is not on fixed entities and on how they are supposed to explain the shape of a new artefact but rather on how elements of different nature relate, change, and move on (or not) together in design practices.' (Storni, 2010, p.27).

It is debated in STS that studying disorder, confusion, failures and detour, which are also constructive moments of design (ibid.), helps to account for the complexity and heterogeneity of the design.

As a working definition of design I will use the one provided by Storni (2010): '...design can be defined in general terms as the set of interconnected and heterogeneous practices aimed at bringing a new artefact into being.' Storni (2010) suggests that design practices are characterised by both constituents (designers, their skills and tools, the infrastructure etc.) and aspects (e.g. physical, industrial or artistic, functional or aesthetical) that 'come and work together around the concrete creation of a new artifact ready to be appropriated by users' (ibid., p.20). From ANT perspective, the design process can be interpreted as a 'process of progressive closure, material construction, mobilization, concentration, stabilization, and organization of heterogeneous resources that precedes the sale and use of the artefact.' (ibid., p.20) Thereafter, it represents a process of 'black boxing' for a network of heterogeneous actors, 'a tendency from an amorphous, vague, and multiply issued object to a black boxed, clearly and univocally defined and concrete artefact' (ibid., p.20). Looking at organisational aspects, design and development can be understood as strategies through which organisations seek to control their environment both physical and social (Law, 1992).

Design and development of a technology is not a linear process, and this can be seen to apply to the Wave Hub project: the process of gradual realisation of the idea including the construction of a physical artefact was controversial throughout, and the end result defers significantly from the original design.

In this case study some of the accounts contrast with published official information about the design of the project, and this makes the study of the design change especially interesting. It should be noted that the version of the design change which is in conflict with the official version emerged in several accounts only in response to direct enquiry and specifying questions.

Constructing a project like Wave Hub can be seen as a ‘hybrid’ engineering problem, as it touches on the renewable energy technology, the economics of building this infrastructure and economics of marine energy, the geo-physics of the location. It also involves social engineering in the form of local perception and acceptance of the project, complexity of the consenting process, the skills of the people involved in management and construction, other psychological and sociological aspects.

The detailed elaboration of the idea of a testing site for wave energy converters was implemented through a feasibility stage, when the crucial decisions about how the idea can be brought into practice were made. At this stage SWRDA relied heavily on expert advice, involving the consultancies and other organisations, each bringing different level of expertise, forming together a multidisciplinary team.

The studies and reports prepared by experts on behalf of SWRDA (Technical Feasibility Study, Legal Report, Business Case) present what can be called a ‘sociotechnical scenario’ which was defined by Law and Callon (1988) as ‘a plausible proposal for a revised network of both social and technical roles that does not rest on an a priori distinction between human beings and machines’ (Law and Callon, 1988, p.287). Technical Feasibility Study is probably the most interesting document for the purpose of this chapter, as it defined the Wave Hub and the preferred option, the engineering option and it gave some of the background into the economics of the project.

In analogy with Law and Callon (1988), it can be said that the proposed technology and its design were part of the ‘social theory’ of the project developers (i.e. SWRDA) as it reflected their notions about the development of the industry, their understanding of the needs of the companies – device developers, the suggested state of technologies (PCUs) etc. Thus, this social theory became a part of the proposed technical solution. The technology itself (Wave Hub), as perceived by the managers, would become a solution for a number of interrelated problems[147].

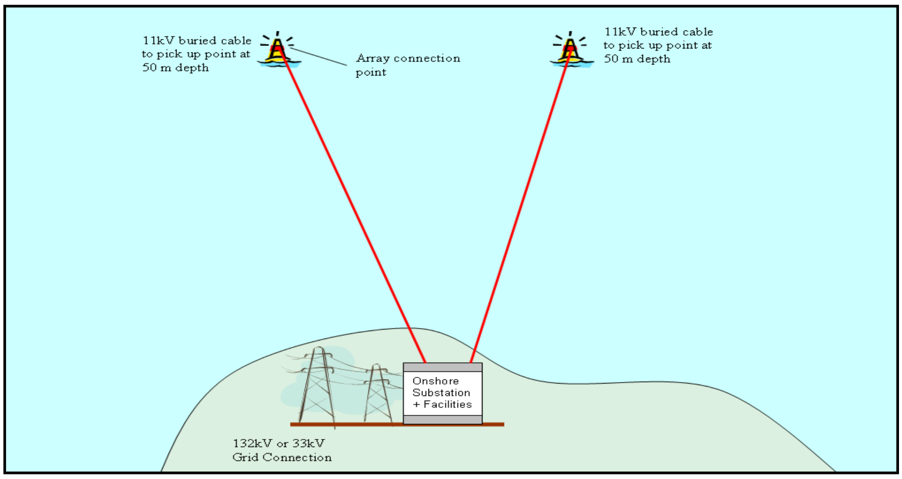
[147] See the mission of Wave Hub in Halcrow Group Ltd/SWRDA, 2005. *Wave Hub Technical Feasibility Study. Final Report*. p.2.

As explained earlier, the intention was to build a wave energy testing site where multiple renewable energy technology companies would be able to take advantage of shared, expensive infrastructure provided for them by SWRDA, thus reducing their own development overheads and allowing for enhanced deployment conditions.

Initially, fourteen concepts as potential Wave Hub design alternatives were identified. These were split into four categories: sub-sea, shore-based, platform and floating with a few design options under each category. The design alternatives were represented in a diagram showing design options as in Figure 6.

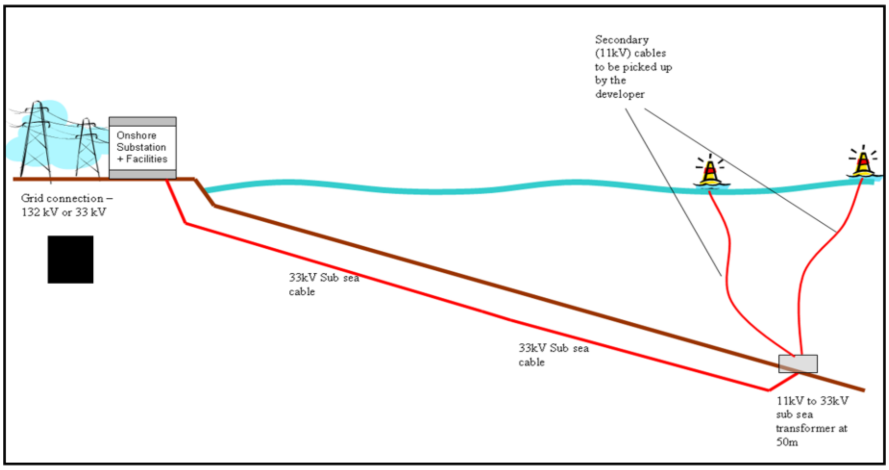
Fig. 6. Design options [148]

1. Shore based Wave Hub facility with multiple cables

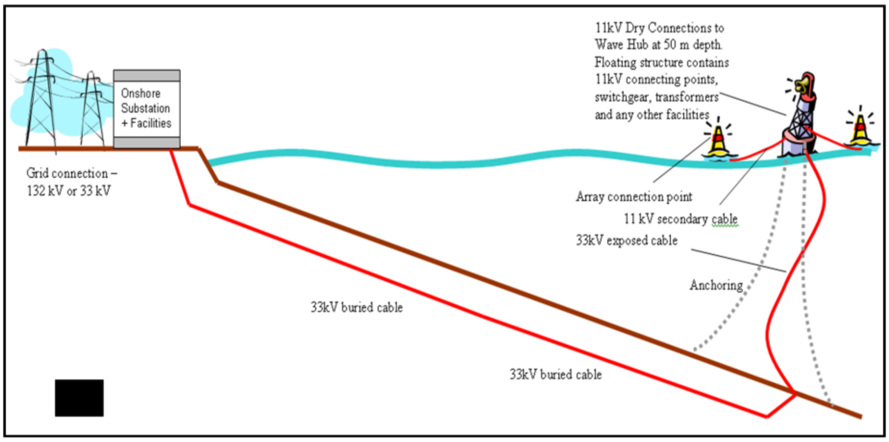


[148] Source: Halcrow Group Limited/SWRDA, 2005. *Wave Hub Technical Feasibility Study. Final Report*. http://www.wavehub.co.uk/wp-content/uploads/2011/06/2005-January-Wave-Hub-Technical-Feasibility-Study-Final-Report.pdf

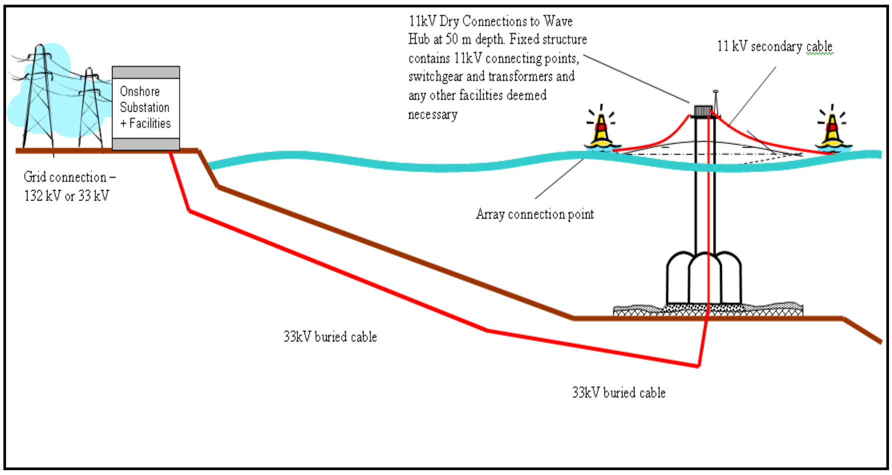
2. Wave Hub with underwater transformers



3. Purpose built floating Wave Hub

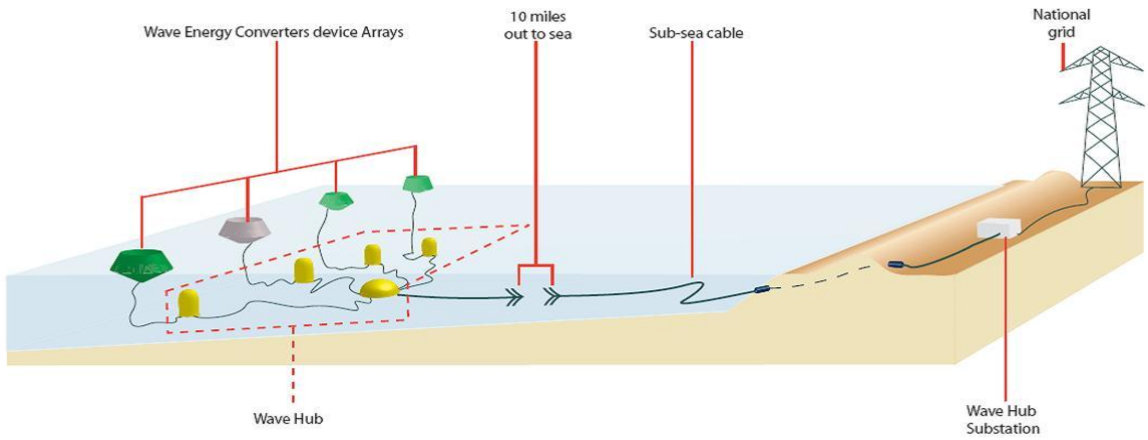


4. Purpose built concrete gravity structure



A ‘wet hub’ concept utilising underwater transformer technology was chosen among several concepts. According to the Technical Feasibility Study, the reasons for favouring this option were the following: relatively low capital cost, minimum equipment is installed offshore; the sub-sea equipment is not exposed to storm damage; the system can easily be relocated; minimum visual impact; no additional support structures are required. Justifying the chosen ’principle’ (a subsea hub) in the interviews, the participants saw it as ‘the safest thing to do’, as the risks of damage in an aggressive environment and of vandalism are high.

Fig. 7. Conceptual illustration of Wave Hub (final outline design – the original diagram of Wave Hub)[149]



The decision was presented as the most reasonable and there seemed to be little doubt that the technology concept was technically feasible. It was planned that the cable running on the seabed would split into four and there would be electrical transformers on the sea bed to efficiently transmit WEC output through the cable to the shore (converting the electricity from the WECs to a higher voltage). It was concluded that a 33 kV[150] connection would be a suitable transmission voltage: the

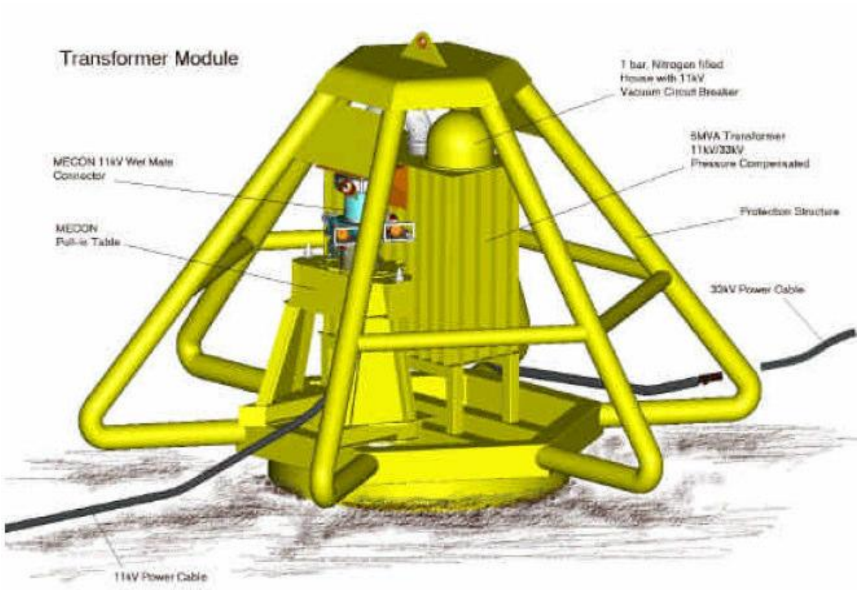
[149] Source: Halcrow Group Ltd/SWRDA, 2006. *Wave Hub. Non-Technical Summary.* http://www.wavehub.co.uk/wp-content/uploads/2011/06/Non-technical-Summary-June-2006.pdf
[150] kV in an abbreviation for kilovolt(s), 1000 volts. A volt is a unit used to measure the force of an electric current (Collins Cobuild Advanced Learner’s English Dictionary. New Digital Edition 2008 © HarperCollins Publishers 2008).

higher the voltage is the smaller the cable needs to be to transmit it, but the cable had to be of a certain size for transmission in order to be physically protected from the marine environment. So the armoured cable about 150 mm in diameter was seen as the best option. Another presumption crucial to developing a concept design incorporating transformers was the standardised nature of the devices (WECs). It was suggested that most of the devices could generate electricity at 6.5 kV, because company X,[151] who was seen as a potential customer (most likely), had a device with these characteristics and was fairly small to mount a PCU on board. Thus, it was suggested that there would be a need for transformers that would increase the voltage to 33 kV for transmission to the shore. (P1, P2) The engineers' explanation of need for transformers was based on calculations which aimed to prove the rationale behind the decision.

According to technical documentation, each WEC unit or interconnected array would be connected to a power connection unit comprising a 33/11 kV transformer built inside a protective clam or shell framework. PCU was characterised in the Technical Feasibility Study as 'existing and proven equipment being used in the offshore oil and gas industry' which 'includes 11/33 kV – 5 MVA rated transformers and sealed for life switchgear for underwater installation' (p.45).

[151] Anonymous

Fig. 8. Transformer / Power Connection Unit (PCU)[152]



The design was not questioned (the Technical Feasibility Study was largely accepted as proving its credibility) until the task to execute the project and take it further was passed to another company. Design solution became problematic from the point of a new managing company who was known as having expertise in offshore engineering. As a result, the design of Wave Hub, eventually implemented in practice, differs from the initial one. As explained by the representatives of the engineering company, additional studies and 'objective reviews' were conducted, more 'front end engineering design' was done, simplifying the 'challenging' concept and deleting subsea transformers from the underwater system, as well as adding more definition in terms of the cable size and routing. Giving credits to those who elaborated the concept of Wave Hub ('design studies <...> it was of a very good quality'), the review process is perceived and presented as normal common engineering practice ('business as usual').

The final construction is described in the official documentation as follows:[153]

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[152] Source: Halcrow Group Ltd/SWRDA, 2005. *Wave Hub Technical Feasibility Study. Final Report*. http://www.wavehub.co.uk/wp-content/uploads/2011/06/2005-January-Wave-Hub-Technical-Feasibility-Study-Final-Report.pdf

'*Wave Hub is connected to shore via an armoured subsea cable which consists of twin 300mm² 33kV power triads and fibre optic cables. The cable is terminated onto two isolated busbars within the hub chamber on the seabed and each busbar will service two berthing areas via four 300m 'tails', one for each berth, made up of three core 120mm² 33 kV cable, operating at 11kV.*

Each customer will connect to the Wave Hub by means of an umbilical that will run from the lead device of each array to an 11kV dry-mate connector on one of the Wave Hub tails. One half of the connector is fitted to the cable tail and the other half will be issued to the Wave Hub customer. The connectors provide electrical and fibre optic connection.

Wave Hub's subsea cable connects to a new electricity substation at Hayle on the north coast of Cornwall via a pair of 400mm² 33kV onshore cables on the beach. The substation comprises an 11kV/33kV transformer with associated switchgear and power factor correction equipment to ensure delivery to the grid within specification.

Control and monitoring of wave energy devices is performed remotely via fibre optic cables within the main cable. Power metering is performed at the lead device on each array and at the substation exit breaker.

Grid connection is via the Western Power Distribution substation at Hayle. The Wave Hub system will operate initially at 11kV and is capable of delivering 16-20MW of power. Once the industry has developed subsea components for 33kV operation the system can be run at 33kV, allowing Wave Hub to accommodate up to 50MW of devices.

Four separate berths are available to lease, each with a capacity of 4-5MW. Wave Hub can readily be upgraded for up to 50MW of generating capacity in the future once suitable components for operating the cable at 33kV have been developed.'

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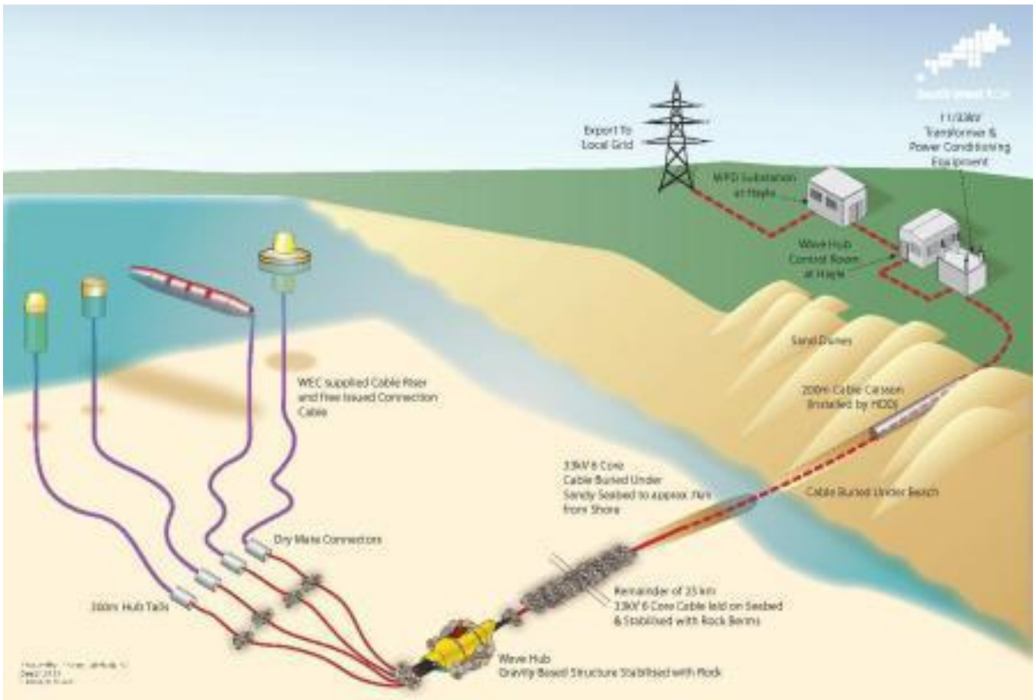
[153] Wave Hub. *Technical Information for Developers*. http://www.wavehub.co.uk/information-for-developers/technical-information/

Fig. 9. Schematic layout for Wave Hub (current official representation)[154]



The explanations for the change of the initial design, provided by different participants, vary. It was interesting for me as a researcher to see different understandings and explanations for the design change provided by different participants that speak to my argument concerning both possible history of the project and how variability of accounts features in the construction of a macro-actor.

One of them is mainly hinged on contested natural conditions in which the hub would operate: '...we found that you could not buy proven transformers to work on the seabed.. You could buy them but they haven't really been proven. They have been proven in very deep water.. but the very deep water is very cold, and you have to keep your transformers cool because they produce heat.. So the fact that they work in very deep, very cold water does not mean that they are going to work in shallower water.. and we were advised that the risk of these transformers not working was very high.. So the design now does not provide transformers on the seabed.' (P1) As it is further explained, some devices (and the most probable potential customer among them – company X) are fairly small and there is no space on board for a power

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[154] About Wave Hub. http://www.wavehub.co.uk/about/

conversion unit (PCU) as this would completely change the idea of the device. So a PCU is necessary on the sea floor for this sort of devices, and that's why initially the project developers thought that most devices were going to need a PCU. So it was incorporated into the design and that was part of the initial concept. Later, company X developed its own PCU which is tailored to its particular device. The project developers assumed that other device developers probably would prefer to do the same instead of connecting their devices with their own sensitivity to a standardised piece of equipment that might not necessarily do what they wanted to do. At the same time, it was admitted that '...it's still an engineering problem that somebody has to overcome, and I see perhaps in the future if Wave Hub took an invitation from one device developer who didn't have its own PCU and very keen that Wave Hub provided that service for them then perhaps Wave Hub might incorporate one as part of the berthing agreement with a developer.'(P2)

A slightly different explanation is provided by those who were executing the construction of the project. Seeing the initial design as a highly technical solution, they suggested that '...perhaps, something was over engineered, there was something which was nice to have but not fundamental to it.' (P11) 'A very simple junction box with no moving parts' was offered instead. The main principle to follow was seen as 'simplicity' which in turn increases durability and viability of a technology: '...at the minute you start to increase complexity in the marine environment you start to increase the risk of failure. So a very simple analysis suggest that anything you do in a sea.. you have to be prepared if you make it complex for it to fail.' (P16)

From the engineers' point of view, the final design was a result of a number of compromises between reliability, cost and feasibility, and the implemented solution can still be questioned: 'Did we get the design right? I think there are different ways of doing it. All of the work and grand design is a series of compromises between technical complexity, how much money you have, proven technology, all different series of things that you have to wrestle with. <...> So it's all about the trade of design.' (P16)

The representatives of the engineering company present their approach as objective and realistic, always referring to 'a reality of working offshore'. From their point of view as experts in offshore engineering, there seems to be a 'reluctance' to build offshore renewable energy industry on the 'huge' experience (technology and skills) that the nation has in the offshore oil&gas, which is not fully utilised by the renewable energy sector. These knowledge and skills are seen as a flexible resource that can be integrated into new sociotechnical arrangements (i.e. renewable energy). Giving a critical assessment of the practices in the renewable energy sector, the engineers also point to the financial problem for the industry '...sometimes we have seen in renewables sector people are doing things which are very odd, you know, sort of high risk construction strategy are not neat and robust enough which from the oil&gas background you would know not to sort of cut corners and this sort of things.. A lot of this comes down to again, possibly the tighter squeeze on the finances.' (P4)

The effect of these changes on the project is seen as significant: '...the very fact that we were not installing those transformers did have serious effect on the offer the project was making. It is quite a significantly different project in terms of engineering than what it had been originally. <...> All it [hub] does it breaks one cable into four cables. It does nothing else than that.' (P1)

The reduction of the initial projected capacity from 20MW to 4MW 'as a result of subsea station being ruled out' (P9) was mentioned in a few interviews, but this suggestion is neither supported by the rest of the interviews, no by the documentary data available. It can be suggested that at certain stage of the project development the worries were there, and the theme of reduced capacity is brought into focus to make the critique sound sharper.

In my reading, the accounts contain definite inconsistencies in regard to the motives for design change and pose a difficulty in identifying the main crucial factor for this change – is it because company X has its own transformers incorporated in their device or the 'failure' of transformers to be installed at Wave Hub. The critics of Wave Hub suggest that technical plausibility was not properly being questioned at the deliberation phase, although broader plausibility of the project (the idea of developing wave energy in the South-West and building a testing facility) was explored, justified and extended to the stakeholder community.

It is noteworthy, that some participants, closely involved in the actual construction of the facility, view the situation with design and transformers mostly as a technical, engineering issue. While a few others who are remote from the decision-making process and who perform more as detached observers consider it mostly as a 'managerial failure', which is interwoven with the expertise and professionalism, firstly, of those organising and managing the project at the early stages, and secondly, those developing the concept and design solution.

Design was more of an internal problem, a problem that was solved in-house, by experts. Another principal question beside the design of the hub itself (electrical equipment on the seabed) was the location of Wave Hub, and it required the involvement of a large number of other stakeholders. Both interview data and documents suggest that a number of factors must have been taken into account. The site for Wave Hub became a major point of criticism and negotiation in the course of the controversy.[155] The process of choosing the location for Wave Hub is closely interwoven with building a consensus with other users of the sea. Some respondents, despite the complexity of the problem, saw it as a fascinating subject!

As suggested in the literature, two concepts to deal with landscape issues exist – 'planning' and 'siting' (Nadaï, 2007), which can also be considered in relation to marine energy and marine landscape. Rational planning is a method used to deal with large-scale issues (national or regional) and works in a top-down manner, 'considering the whole to decide on the destiny of the parts' (ibid., p.2716). The advantage of rational planning is that it extracts from the territory a simplified representation and simplifies policy processes. Siting concept has a different logic,

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[155] The existing studies assessing public responses to installation of Wave Hub explore some of the controversies over the location of the project. For example, Connor (2007) explores the objections based on the recognition of contingency of data collection and inadequacy of data related to the potential reduction of wave height that was important for surfers; McLachlan (2010) discusses a critique of the location of Wave Hub which is associated with the aesthetic qualities of the project voiced by local dwellers. Public attitude, 'stakeholder responses' to wave energy developments and public engagement are also discussed using concepts of risk and reward perception (Bailey et al., 2011; West et al., 2010).

and the emphasis is on the social dimension of the planning process based on the participation of different social groups, agencies and individuals; operated at the level of locality and ties durable social links because it explores and integrates social networks (ibid.). According to Nadaï, (2007), rational planning is based on a 'framing' logic: it aims at optimising social welfare on the basis of an ex-ante [based on forecasts rather than actual results] spatial scheme, while siting 'overflows' (referring to Callon's pair of concepts framing/overflows). It is admitted that the apparent efficiency of rational planning as compared to the complexity of siting processes makes it tempting for policy makers to answer to siting issues with hierarchical planning tools (ibid.).

In case of Wave Hub the size of the project, the (institutional) allocation of decision power and funding, the territorial scale for decision making (national and regional) determined rational planning logic to prevail. The decision making was not fully delegated to the local authorities as Wave Hub is recognised as a national asset and funded partly by the UK Government and EU. So it looked logical to project developers to start the process as 'rational planning' which at the same time incorporates the elements of 'siting', although the public participation and opposition would not be able to make radical changes (to cancel the project, for example). Public participation was also 'planned' to some extent as an element of a rational planning.

The existing substation in Hayle, North Cornwall defined the boundaries of the band along the edge of the cost – the proximate area for Wave Hub site. The first factor to consider in developing a concept of a wave energy project was what were the best energy resources available? Previous studies (of resource assessment and developers preferences) suggested that siting a WEC on the surface in water with a depth of 50-60 metres, where energy resources are the strongest, would be optimal for harvesting wave energy. Moving further offshore would also reduce the visual impact, and this was seen as an advantage. For the choice of the location for Wave Hub (area in the sea) it was important to bear in mind the preferences and needs of the target group – the companies who were seen as potential customers and who had displayed interest in using the site. As it is known from the history of the project, preliminary study was conducted to picture the needs of the device developers (as part of the Technical Feasibility Study). Presuming an exclusion of certain type of wave energy converters (nearshore and onshore devices), the managers confirmed that from the beginning they targeted a type of devices that ‘have been really quite developed at quite a good stage’, and that there certainly would be devices that cannot use the facility. In the meantime, the development of a number of nearshore devices had come to fruition, and ‘it’s unfortunate that Wave Hub doesn’t help them’.

At this stage, new actors whose interests might be affected by the project were consulted, and those who must grant various consents[156]. Among them there were the professional fishing community (fisheries organisations), research organisations, environmental groups (including Surfers Against Sewage), local businessmen, archaeologists, the statutory bodies and NGOs, etc. The negotiation process illustrates how the management team constructed the consensus achieved and how in turn the very idea of consensus was constructed.[157]

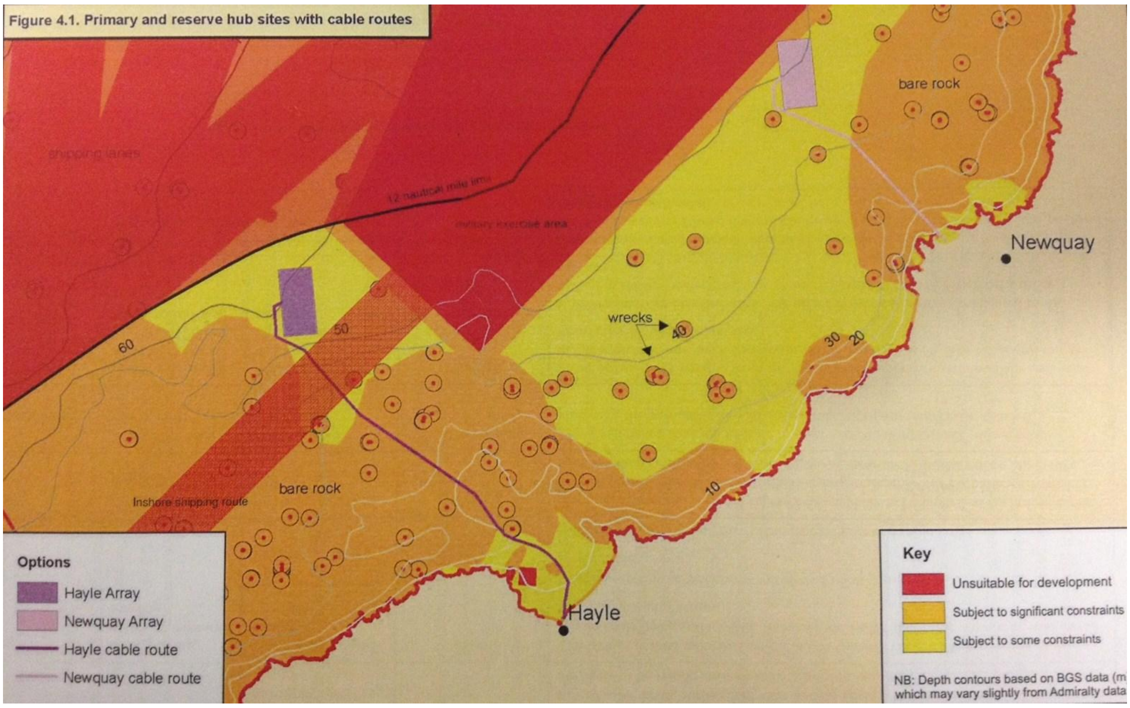
The participants pointed to the factors that had to be considered by the management team, what they had to deal with, and in totality suggested a consenting process which was perceived as very complicated.

Certain areas in the sea had to be avoided, and relevant information was collected in regard to the possible location of Wave Hub. The fishermen were asked about their fishing areas, and the costs of leaving the area unfished was calculated; information about navigation track plots was obtained from the Navigation Authorities. There was leisure traffic to be taken into account and a military practice area. Seabed conditions were also extremely important as the project managers wanted to avoid ‘a rocky pinnacle seabed’, and they had to consider ‘exclusion zones’ around different types of wrecks which are very valuable to archaeologists and protected – ‘wrecks of boats, submarines, fishing boats, liners...’. ‘...And it’s pretty harsh sea conditions that [there have] been wrecks all around the South-West for hundreds of years.. and they are very valuable to archaeologists, you can’t just dig a cable root through wrecks on

[156] See Appendix B ‘Consultee list’ in Halcrow Group Ltd/SWRDA, 2005. *Wave Hub Technical Feasibility Study. Final Report*. http://www.wavehub.co.uk/wp-content/uploads/2011/06/2005-January-Wave-Hub-Technical-Feasibility-Study-Final-Report.pdf
[157] For more details about controversies around Wave Hub location see chapter 4.

it.. Even if you avoid the main wreck, with a wave and a tidal action you find a dispersal side around the main wreck where cannons and grates of this and.... and gold coins and bodies of sailors can be found.. And that's protected.' (P2) Overall, the proposed location of Wave Hub was characterised as 'a very busy place in the sea'.

Fig. 10. Primary and reserve hub sites with cable routs[158]



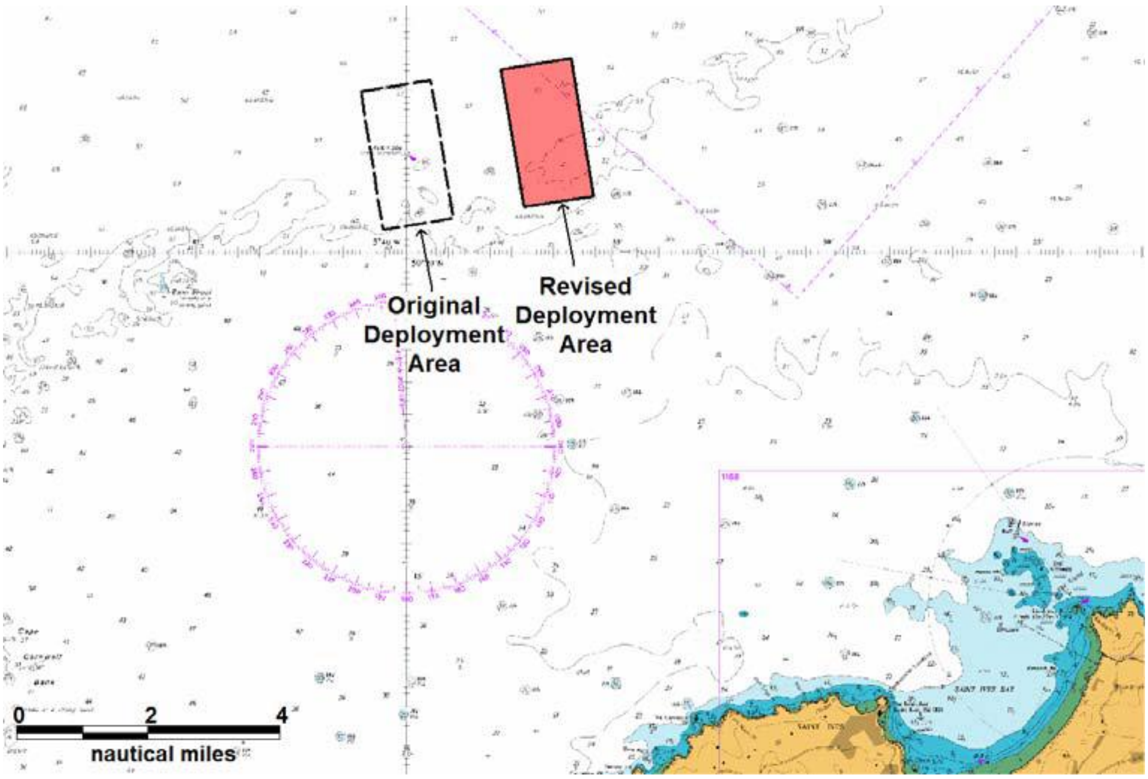
This story also illustrates 'how the memory and the identity of the place emerges through multiple channels' (Nadaï, 2007) as the project gets developed (e.g. found wrecks on the seabed; biodiversity is described by scientists; the wave climate is studied; users of the sea are recognised etc.).

My participants agreed that this process was extremely controversial. It was vital for project developers to settle the possible disputes, or at least to present them as resolved. This would mean that the final decisions could be recognised as legitimate and be accepted by all (or majority) of the stakeholders. For achieving that, the

[158] Source: Halcrow Group Ltd/SWRDA, 2005. *Wave Hub Technical Feasibility Study. Final Report.* http://www.wavehub.co.uk/wp-content/uploads/2011/06/2005-January-Wave-Hub-Technical-Feasibility-Study-Final-Report.pdf

project developers were ready to compromise on issues that would not significantly undermine the very concept of Wave Hub and its viability. Navigation Risk Assessment consultations concerning the potential deviation of vessels can serve as a good example. To minimise the concerns of influential stakeholders and to reach a compromise, the Wave Hub site was moved '4km ENE to the very edge of the regional survey area'.[159] As a result, the location was presented as 'the preferred offshore Wave Hub site' constrained to the West by potential marine traffic risks, to the East by the MOD[160] area and known wrecks, to the South by a relict cliff line with a change in depth (to ~37m) and wrecks, to the North by the 12 nautical mile limit and more wrecks.

Fig. 11. Chart Overview of the Revised Wave Hub Location[161]



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[159] Halcrow Group Ltd/SWRDA, 2006. *Wave Hub Development and Design Phase. Final design report*. http://www.wavehub.co.uk/wp-content/uploads/2011/06/Wave-Hub-Final-Design-Report.pdf
[160] MOD – Ministry of Defence
[161] Source: Halcrow Group Ltd/SWRDA, 2006. *Wave Hub Development and Design Phase. Final design report.* http://www.wavehub.co.uk/wp-content/uploads/2011/06/Wave-Hub-Final-Design-Report.pdf

According to the respondents who represent the management team, the design decisions for the Wave Hub project reflect the ‘objective reality’ and have strong reasoning behind. It is important to remember that the design solutions for Wave Hub were correlated with the state of the development and the structure of the wave energy industry, with the momentum when only limited number of devices were quite advanced to show interest in Wave Hub. This can probably explain some of the decisions made. But what seemed to be a reasonable and credible solution at the time of the project development might appear to be short-sighted and narrow-spirited later on. This brings back the question of modifying a master narrative for Wave Hub and possible diversification in relation to other offshore energy developments. Nevertheless, the possible changes are unlikely to radically alter the design of the facility since its implementation in a material form. This corresponds with Storni’s suggestion about stabilisation of artefacts: ‘the closer we get to a concrete, singular artefact, the more the social and the technical, the agency and the structure, and the object and the subject, are fixed and appear stable and separated, and so too their interdependencies’ (Storni, 2010, p.21).

6.3.2. From ‘failures’ to ‘lessons learned’

6.3.2.1. Accounting for ‘failures’

It can be suggested that credibility of a technology is partly built through justifying failures, including delays. Justifications, as well as excuses, are ‘highly conventional acts’ in discourse (Potter and Wetherell, 1987, p.76). In the Wave Hub case the problem of failures appeared to be a common theme and was widely discussed in the interviews. It was often questioned if all choices were justified and were made as a result of expediency. In this section I will explore how the notion of failure was constructed, what was legitimised as possible causes of failure and possible solutions and why the decisions made were seen as the only solutions.

The official information available to the general public does not include details about the difficulties experienced by the project developers and minimises the role of changes in design, delays and problems at different stages of the project development. It is a story of a ‘success’. Nevertheless, as the analysis shows, and it was admitted by the participants, the project experienced a number of so-called ‘failures’, some ‘mistakes’ were made and, as a result, the lessons learned. As it was admitted by a representative of a management team, ‘no one likes to portray their problems in public’. Retrospective accounts for the failures and mistakes along the way were presented by the participants in response to specific questions and/or requests for further clarification in discussions. Participants were also prompted to discuss the lessons learned out of their involvement in the project. The participants, and it is especially important for those who were working on the project, were openly talking about the difficult moments they experienced. This can be possibly explained by their willingness to show the complexity of their work which gives them credit and demonstrates the uniqueness of the experience they gained.

Different groups of the participants see different aspects of the project development as problematic. Among those who were directly involved in the execution of the project, the question about failures and mistakes provokes the discussion about the technical problems and other difficulties they experienced throughout the delivery of the project, and often involving third parties such as contractors and subcontractors (e.g. for construction process, tendering and contracts). For example, one of the managers pointed to a failure with a floatation system to float the cable off the cable-laying ship which required a development of a new floatation system and modifications of the vessel to make it happen (which was very costly as well). These kinds of mistakes, or ‘wrong decisions’, are not perceived as fundamental.

Another complication that the project faced along the way was an escalation in cost. ‘They did this big tendering process which ultimately failed because the bids came in far, far too expensive.’ (P11) The failure of the first tendering process led to the changes in the management to find more cost efficient solutions. The cost of some operations (parts of the project) also appeared to be higher than expected: ‘We had also at the early stages underestimated what we needed to do to protect the cable and secure it to the seabed. <...> the sea is very rough in that area, so in heavy sea the cable will move, and as the cable moves it becomes damaged and it would just fail. So we needed to put a lot of rock on top of the cable to hold it in place. <...> It is buried where it can be but the seabed is sand only for the first 5 or 6 kilometres of the shore. Beyond that it is rock and in most places the cable has to be held down.

We have previously underestimated how much we would have to do to hold the cable in that position.' (P1)

A more detailed explanation was provided by those who were executing the offshore construction and, in particular, the cable-laying. The socio-economically motivated preference for the rocky seabed did not allow burying the cable below. The alternative means to protect it was rock dumping which was seen as an optimal method for the Wave Hub. Explaining the process of rock dumping, the engineers referred to this technique as very effective but quite costly; the 'almost unique size of rock' that they needed (to be big enough to be stable but small enough to minimise the risk of damaging the cable when you drop it down) was obviously very expensive. The need to optimise the protection method required more studies to find the right balance: 'You can't just keeping on putting more rock, can be two reasons: one – it's the cost increases dramatically, and two – from a licensing view point. We had a duty to minimize the amount of rock we were going to put on the cable.' Admitting underestimation of the cost of providing protection to the cable, respondents characterised the first result of the tendering process as a 'nasty shock' as the prices for rock dumping were 'effectively double' what they were planning for. The escalation of the cost and the delay with cable manufacturing led to an 'innovative' solution which they were very proud of – to use flexible concrete mattresses (which initially were supposed to protect the cable temporarily before rock dumping) and put them on top of rock, as the time interval between two operations (cable laying and rock dumping) was minimal and there was no need to put the mattresses on the cable temporarily for its stabilisation: 'So we used mattresses to protect the rock. <...> just discrete intervals. Even if you get this hundred-year storm, and we do get some of the rock washed away, we know we are still anchoring the cable at suitable intervals. And in such circumstances you might have to go and do some additional maintenance work at some stage, but the cable is always going to be protected.' This solution reduced the cost significantly and allowed certain compromises in regard to the rock size – some degradation of the rock which was initially chosen 'marginal from a long-term stability a hundred year storm condition'. (P4)

The problems experienced with the consenting process, which were discussed in detail constructing a historical narrative, are seen as the 'biggest barrier' which could be 'a real show-stopper' for the project progression (for those involved in the process). The 'nervous moment' created and concerns of the consultees and regulator are explained by the novelty of the project. 'If everyone is really nervous... they just express support for the scheme like 'yes, we support the scheme in principle' because who wouldn't? You wouldn't say 'no' on principle, but they are very concerned about all the little details.' Although, as it was admitted in the interview, not all of the concerns were addressed eventually (e.g. concerns expressed by the Chamber of Shipping). Sometimes, the decisions are made on the basis of 'for the purpose of the greater public good'.

The key message that runs through the interviews created a feeling that the development of Wave Hub probably couldn't have been done another way or done better. The main argument repeated in most of the interviews as a justification for mistakes and pitfalls is the novelty of the project: 'We just faced so many difficulties and one of the greatest difficulty is that nobody has ever done this before. And if you are the first person to do something then everything you have to deal with, you have to invent an answer. And all the people you are dealing with, they have not dealt with it before either, so they are having to find their way forward. <...> Yes, learning by doing, absolutely in every case. So many aspects of the construction, many aspects of the consenting process... nobody had ever experienced it before.' (P1) 'Considering how novel this process was, no one has done it before.. that was pretty well.. it's not surprising that there are some hiccups along the way, but it's clearly has been a success.' (P11)

Those participants who are more critical about the success of Wave Hub often talk about 'failures' in regard to the project as a whole. As the biggest problem they see the management failure regarding the non-existence of the subsea transformers and the 'econo-technical problem' of the absence of any significantly advanced WECs to be located at the Wave Hub, especially in arrays: '...the berths are empty at the moment and that's a little unfortunate. It's not quite how we imagined it when we started the project. We were given to believe that there will be a real demand, lot's of device developers would receive funding to develop enough devices for 5 MW array and then they can do a commercial testing and then in turn would create confidence in their device and they will be able to go and manufacture hundreds and hundreds and sell them over the world based on the test results at the Wave Hub site.' (P2)

The introduction of the new management company (JP Kenny) was not a part of the original plan, and in the eyes of some of my respondents also represented a sort of failure, an indication of a 'project being improperly managed'. (P9)

The unmet expectations raise serious concerns about the future of the facility, its utilisation. The uncertainty and financial difficulties experienced by the wave energy industry have a serious impact on Wave Hub, and it is not clear when it eventually be populated: '...developers struggled to get money. <...> because it's a nascent industry it's just been born and it's just growing it takes an enormous amount of research and development money, and there's no guarantee if you are an investor in marine renewable energy that the device that you are investing in is going to be a winner. And if it's not a winner because someone invents something just a bit cleverer, then you wasted your money. And I think, there is a certain fear that any money that invested by private investor could just disappear.. it's risky.' (P2)

As such, the project itself and the related 'market' were characterised as having huge potential but 'very fragile'.

6.3.2.2. Serendipitous nature of delays

According to the documentary data, in the initial project development schedule the assumptions ('working assumptions') were based on the experience from offshore wind power installations and represented 'the minimum reasonable time' for different stages, such as the preliminary studies, engineering, tender processes, procurement, installation and commissioning[162]. At the same time, this programme was recognised as challenging and dependent on a number of factors. It was clearly stated that consenting and funding processes, being the most critical, are only partly within the control of those driving the project. The factor that allowed the project

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[162] Halcrow Group Ltd/SWRDA, 2005. *Wave Hub Technical Feasibility Study. Final Report.* http://www.wavehub.co.uk/wp-content/uploads/2011/06/2005-January-Wave-Hub-Technical-Feasibility-Study-Final-Report.pdf

developers to be optimistic about the timing and progress of the project was the support from the policy side – 'a strong will within DTI, DEFRA, Crown Estates and other relevant organisations to support the industry in general and this initiative in particular'[163].

Even at an early stage of the project development (consenting process, tendering), it became obvious to the managers that the contractual milestones could no longer be met. As my respondents suggested, it was partially because of the design change, but also largely because of the difficulties elsewhere in the programme such as financial and managerial issues.

Nevertheless, when it became apparent that there were no WECs to deploy at Wave Hub around the time of its initially planned commissioning (that was set up at the beginning of the project[164]), the attitude to those delays changed – the delays turned into a factor that worked in favour of Wave Hub, strengthening its credibility, not undermining it: '...So actually the delays in the development of Wave Hub have worked out pretty perfectly, cause if they had deployed that thing two years ago when they potentially wanted to, it would be sat into water for two years with really no devices that would be able to take advantage of it. Cause all of the devices had redesigns, redeployments, and so technically the market was such that it would be hard to push people out there.' (P5)

In response to the remark about the possible positive effect of the delays with the project delivery, the manager's reaction was unequivocal: 'Absolutely! Otherwise we would be waiting for even longer.' (P16)

Although delays with a project delivery are usually seen as a negative factor that undermines credibility of the project and the managers, as well as causing extra expenses, in the case of Wave Hub the perception of delays at the time of the field

[163] Halcrow Group Ltd/SWRDA, 2005. *Wave Hub Technical Feasibility Study. Final Report,* p.70.
[164] According to the schedule outlined in the Technical Feasibility Study, the construction of Wave Hub is to end in autumn 2006. This timeframe is characterised as challenging and some delays were seen as possible and acceptable due to possible environmental impact on the marine operations and the construction schedule.
According to the official information, Wave Hub was deployed in summer and autumn 2010. (Wave Hub Project History. http://www.wavehub.co.uk/about/project-history/).

work was not so dramatic. Even more, the delays were hailed and described as ‘lucky’.

The reasons behind such perception of delays were also explained by the participants. The main idea is that Wave Hub, in their opinion, was ahead of the time, it was too early for the industry to use this facility and it could take a few years more before someone could install the devices in arrays at the Wave Hub site. It is paradoxical, but the delays became a positive factor for constructing credibility of the project.

6.3.2.3. Lessons learned

This theme appeared in the interviews with the management team and those who were closely involved in the development and construction of the Wave Hub project. Along with acknowledging some pitfalls with the project delivery, the participants willingly talked about the lessons they learned from the project.

Not surprisingly responses about the lessons learned correspond to failures, mistakes, delays and difficulties experienced. The assumptions and conclusions made by my respondents are of two kinds: an experience regarding practical aspects which sometimes can take a form of a review of ‘best practices’, and more fundamental points (general reflection) in relation to the whole concept of Wave Hub.

The human factor and communication issues appeared to be crucial for the managers. This includes both the relationships and interactions between those people who work on a project and take it forward, and ‘a very strong client internal team’ which means in-house expertise in project management and capabilities to understand the technology-related issues. One of the participants used his own term – ‘a challenging client’ – to emphasise that it is important to challenge contractors and consultants by demonstrating your awareness and comprehensive understanding of the details of every delegated task.

A few other issues in terms of improving the management practice were brought into focus. What seems to be a common theme here is the time frame of the project and various factors that can affect it. In the participants’ view, the project insights suggest, that such factors as involvement of EU funding and the offshore environment need to be assessed carefully at the planning stage as they can affect significantly the time frame of the project and reduce its flexibility. ‘There was a lot we learnt.. If we were starting again we would be able to do it a lot faster because.. [*showing the slides*] this is the time we took to develop a project. We would probably do it three years quicker if we were knowing what we know now.’ (P1)

The participants claim that they gained essential expert knowledge as an outcome of the project: ‘we now understand the consenting and regulation process, we understand the developing market for renewables, we understand all of these things much better than we did before, we understand the commercial side.’ (P1)

For the contractors – companies who were hired as experts in a particular field, the lessons learned were not a prominent theme: positioning themselves as experts, they do not see the project as crucial for their professional development: ‘a fairly minor point’; ‘The end result could have been better, but it doesn’t change anything <..> there are many small areas where we’d rather do this than that or this could be better, but that’s the nature of construction project.’ (P4). For these companies it implies that there are things they could do better not because of the lack of expertise but rather due to other factors, such as involvement at the later stage of the project when some of the parameters had already been defined.

In regard to the concept of Wave Hub, as it was discussed earlier, the respondents admitted the limited character of the offer, and what they would have changed if, hypothetically, started the project again, as ‘wave devices are currently proceeding fairly slowly because we know they have more difficulty attracting money than, say, wind’: ‘We have at the moment quite a narrow opportunity with only wave devices, and a lot of the people that are coming to talk to us want to do something other than wave.. they might want to do floating wind, or they might want to do a tidal device but we don’t have the right consent in place for that.. So we could but it’s a great deal of work to go back and modify the consent.’ (P1)

As such, the initial concept and design of Wave Hub was being questioned at the later stage of development and raised concerns about the future of the facility.

As was suggested by Storni (2010), designing subjects (not only objects) and their practices including their expert knowledge are results of the design process, not causes or preconditions. In the case of Wave Hub, it is not possible to track further design *practices* (which imply an established method or procedure of doing something) of the design subjects – this project was created as single, distinct and unique, but as a result some experience was gained and expert knowledge was gradually developed through failures and search for solutions. A few participants pointed to the fact that they gained 'essential new knowledge and experience' working on this project. Some of my participants (e.g. consultants) use it as a very valuable professional experience that works for their reputation and can be used further for similar projects. One of those who actively participated in the development of the project was proud to say that he was invited to work on other renewable energy projects due to his 'unique' experience with Wave Hub.

To conclude, the conceptual value of lessons learned as a result of the Wave Hub project is accumulated in elaboration of the (design) practices, attempts to revise organisational practices and to form new associations (collaboration), a knowledge sharing (experience) and the enhancement or prove of expert status. The participants' story of Wave Hub relies on the idea of incremental accumulation of expertise. Talking about the lessons learned, the respondents had to acknowledge the problems they experienced with the project (e.g. delays), but at the same time it allowed them to sound a positive note turning the problem of failures and difficulties into a positive statement about new experience and expertise.

6.4. Conclusion

In this chapter I paid attention to the discursive work that has been done when the claims were made to establish credibility of Wave Hub. Discursive strategies that positioned the project as an innovative and anticipated by the marine energy industry and as beneficial for local economy were examined.

I started with the thesis about credibility as a constructed attribute. The official recognition of the project's success, despite of a number of failures and delays, is the evidence of the strength of the credibility construct around Wave Hub.

Credibility of Wave Hub is built upon expert knowledge (presented as such), combined with political support and ideology of clean energy and sustainability (i.e. politicisation of Wave Hub). The perception of renewable energy in society is generally positive, and creates a 'congenial credibility-environment' (Shapin, 1995, p.264) for Wave Hub and for the claims about the benefits for society in general, and for local communities and renewable energy industry in particular. The presentation of Wave Hub as an element of infrastructure and the intention to make it complementary to other facilities (NaREC, EMEC) are important elements of the credibility construct, or credibility-economy.

The varying assessments of credibility and validity of these claims created divergence of opinion about the project's success. The perceptions of the project and its qualities were also not consistent among the participants. This led to the discussion about the symbolic meanings of Wave Hub, which in turn created all together a picture of a macro-actor in its various manifestations.

The success of Wave Hub appeared to be a matter of perspective. What does it mean for Wave Hub to be a successful project? What does it mean for the project to be fulfilled? One of the answers is that it depends on other actors – first of all, device developers and their WECs that can put life into this facility. Does the failure of the wave energy industry to utilise the facility at the time of its construction automatically undermine its credibility? The criteria for success of Wave Hub and its performativity are not clearly defined and can have different interpretations.

The development of credible design solutions was based not only on compromises on technical complexity but also through building a consensus with different stakeholders. The argumentation used to justify what some of the respondents characterised as 'failures' comes along with recognition of some mistakes made and lessons learned.

It can be envisaged that since Wave Hub has been built and exists in a material form, the problem of the credibility will abate, but probably will be complemented with a question of reliability, which will be viewed in a new light as with many other technical systems in the process of usage.

To sum up, the analysis of data suggests that the political and economic interests were mobilised around the credibility of the project. It became a highly politicised affair. The legitimacy and credibility of the project were established on both scientific and political grounds. In modern societies science is recognised as a legitimate trustworthy source of knowledge, so the involvement of experts, including academic experts, was a crucial factor for constructing the credibility of Wave Hub. The detailed analysis of construction of expertise around the project is a subject of the next chapter.

Chapter 7: The politics of expertise: Wave Hub as a focus and source of expert knowledge

'The experts can be persuasive. They can quote stacks of facts and figures. They can give all sorts of logical reasons. They can present plausible explanations. They can also pose difficult questions and point to awkward contradictions in any alternative view. However, the biggest thing going for the experts is that they are thought to be the experts.'
Martin (1991)

7.1. Introduction

The question of credibility of Wave Hub, which is central to the previous chapter, is closely interwoven with the question of expertise and its role in constructing credibility of the project, as well as the question of credibility of different actors, such as the management team, SWRDA, various consultants, research institutions, device developers and the wave energy industry. The theme of expertise and expert knowledge is inevitable when the discussion is formed around a technological project, new technologies, and innovation, which require specific knowledge of the subject and are related to the participants' professional activities. The ambiguities encountered in the case study provoked disagreement, controversial opinions and speculations. Therefore, the expertise and expert status of the participants become important in the discourse about the controversial aspects of Wave Hub. Expert status adds 'weight' to their opinions, shows how the participants position themselves in their professional community, allows them to express their specialist opinion and articulate their concerns. Taking my analysis of credibility further, in this chapter I will explore in what sense an argument can be made about co-production (Jasanoff, 2004) of expertise and destiny of the project.

The analysis of the discourse around expertise and expert knowledge can arguably undermine a 'mythical picture' about science which, in Martin's words, is 'sold to the public as objective knowledge that is untainted by social factors' (Martin, 1991, p.57). In this thesis I am trying to understand what credibility and expertise mean for the participants in relation to the Wave Hub case.

The task of this chapter is to show how the expertise is understood and performed in the case of Wave Hub and for which purpose, how the expert knowledge and the expert status are constituted, to study the contestation of expertise and its categorisation, and to consider the appropriateness of the critique of the experts and managers. This chapter is about collaboration but also antagonism revealed between different groups of experts. The assessment of expertise within the community and by outsiders is also discussed here.

It was discussed earlier that the Wave Hub project was presented by the participants as extremely controversial, with a lot of disagreement and differences in opinions regarding its success and the professionalism of those involved in its development. It was also examined which actors and social groups were involved from the very beginning of the project, shaping its trajectory and what stands behind a strong public interest in this project. Not once were the decisions made by the managers denounced by other stakeholders. Some of the participants believed that there were a number of possible solutions to critical aspects of the project's development, and the decisions made were not always reasonable and justifiable. From the very beginning it was perceived, using Martin's words, as a 'challenge for experts' (Martin, 1996). All these factors make Wave Hub an interesting case for studying the politics of expertise surrounding it and the experts themselves, their status and self-(re)presentation.

Wide publicity, the advertised 'innovative' nature of the project, and the high cost of Wave Hub meant that constructing credibility required presentation of Wave Hub as a project based on solid expertise, accumulating scientific advances and latest technological achievements. The knowledge and experience relating to Wave Hub is perceived as 'unique' by the majority of my participants, mostly due to the novelty of the project. The uniqueness of the development and related expertise is one of the arguments used in constructing credibility of Wave Hub.

Not only Wave Hub itself (as a technological object), but numerous issues surrounding this project became an object of expertise. Multiple objects of expertise were described by the participants. This reflects the multidisciplinarity of the issues surrounding Wave Hub (e.g. biodiversity, wave resources, mooring, electrical engineering etc). The expert knowledge was often discussed as mediated by the use of different equipment, techniques, and other intermediaries used to develop expert knowledge around 'expertable' objects (for example, waves).

Various categories of experts associated with Wave Hub form so-called multiple 'communities of practice' (Wenger, 1998; Bowker and Star, 2002). The analysis of interview data helps to understand what it means for the participants to belong to one group or another, and how they position themselves in relation to each other. For example, some communities identified themselves as academics, consultants, managers etc.

For my purposes, I have distinguished between two domains of knowledge and expertise in relation to Wave Hub in participants' perception: expert knowledge necessary for development and construction of the project, and knowledge (and expertise) gained as a result of the project's fulfilment and existence. Sometimes it is difficult to draw a clear boundary between them, when the same actors possess both – their initial expert knowledge and expert status was a necessary condition to participate in the project, and new skills were developed in the course of the project, often through failures and mistakes.

Notes on my field work experience

I would like to begin this discussion with a few additional notes about my experience during the field work specific to the topic discussed in this chapter. The theme of expertise was deliberately brought forward by me as a researcher – it came out in discussion of the issues around collaboration between Wave Hub, PRIMaRE and other stakeholders, the difficulties accompanying the project development, failures and lessons learned. The participants were prompted to express their opinions about the evolution of the project. The narratives of expertise can be traced in the interviews with different groups, including managers, researchers, consultants and company representatives. The participants were usually very enthusiastic about their subjects and related issues. It was important for the participants (especially academics and some practitioners – consultants and managers) to emphasise their expert status and to define their areas of expertise. Nevertheless, the critique, sometimes sharp, often went beyond one's area of expertise; the use of second hand information was common.

As mentioned in Chapter 3 of this thesis, my affiliation with the University of Exeter played an important role, and especially in approaching the contacts in the academic community. Despite the overall positive attitude to my research project, I received varying degrees of support from different groups of academics. Those who were more helpful with the case study found it unacceptable that a few others dismissed the invite to participate.

As some of the interviews were very focused and involved scientific discourse and/or required specific knowledge of the field (e.g. technical aspects), the use of scientific jargon as well as some simplifications were inevitable. In-depth semi-structured interviews are illustrative of how the participants talk about technical and specific issues with 'outsiders'; this format enables them to discuss in more detail their field of expertise, the problematic aspects of the project and go beyond the simple short answers to the questions asked (e.g. '..I don't want to talk really very technical but because of that length...' [sic]).

The use of special terminology is a distinctive feature of expert discourse. The way in which 'technicalities' are negotiated can show the degree of openness, how formal or informal the participants want to be, how the experts position themselves towards the interviewer and how they want to present themselves (as members of certain community, as professionals, helping to construe the expert status).

Specific terminology (jargon) can help the experts to sound credible, 'scientific' and to demonstrate the deep knowledge of the subject, their competence, as well as the complicated nature of the expert knowledge. Moreover, it can be seen as 'boundary work' in some sense to delineate the boundary and emphasise the expert status. At the same time, in my case it was important for the participants to be understood correctly, despite the anonymity clause, so definitions and explanations were provided for specific terms; further explanations were often offered with the use of visual images, documents and object observation. This approach was demonstrated in face-to-face interviews. The extensive use of drawings for explanation by some of the participants was more typical for scientists and representatives of academic community.

The visual data is highly valued by various communities involved in the production of expertise discourse (academic researchers and experts, commercial experts) and were used widely in discourse and for post-interview data sharing. The references to the previously given talk and presentations were accompanied with the power point slides. For the engineers and people involved in the construction of Wave Hub the use of the photographic images served not only as an evidence and illustration of the 'factual information' in their talks but also as an entertaining element which can ease the perception of the information which can be rather 'technical'.

References to academic publications, i.e. published articles as well as work in progress, were typical for the scientists. The publications serve, in their opinion, as a credible and reliable source of explanation and a good illustration of some points made in the interviews.

The ethnographic observations above serve as a starting point to discuss the Wave Hub project as a focus and source of expert knowledge.

This chapter consists of several sections that include the discussion about waves and wave energy as objects of expertise, categorisation of expertise with particular focus on the politics of commercial expertise and the production of academic expertise around Wave Hub, as well as the main antagonism between them.

7.2. Wave energy in scientific discourse

Waves seem to be a special subject for the participants and for me as a researcher. They are widely regarded as a 'natural' phenomenon, or even as a natural mechanism for the movement of energy. In my research I approached waves from ANT perspective, trying to see how it emerges as a non-human actor within an actor-network. Inevitably, waves and energy that can be extracted from them became a focus of expert knowledge in the case of Wave Hub. Every interviewee mentioned wave energy, but only a few talked about waves themselves as an object of expertise. The analysis of interviews and visual data, as well as relevant literature, can help to gain an understanding of what 'wave' taken as a resource, or source of energy, stands for in the discourses of renewable energy and its quality, and what the features of this discourse are.

It is widely accepted that wave energy is created as winds pass over open bodies of water, transferring some of their energy to form waves (DECC, 2010). This energy can then be captured by wave conversion technologies to provide power either on the shoreline or in deeper waters offshore (ibid.).

A few participants – representatives of the scientific community talked about this natural phenomenon through the lens of 'resource assessment'[165]: '...the initial resource assessment which is basically taking all the historical wave data that we can find, including data from models, recordings and so on. And putting it all together to provide information for developers about what the average climate is, so they can make calculations for power prediction and so on..' (P17). A range of technical equipment and techniques enable them to claim an understanding of the resource and to create a description of waves as a source of energy, studying waves in the natural environment and in experimental laboratories ('using wave buoys, computational simulation and land based radar to quantify the wave energy resource available at the Wave Hub site off the North Cornwall coast'; Wave Tank with programmable wave maker, Recirculating Flume, Computational Fluid Dynamics software[166]).

Utilitarian approach to waves as a natural source of energy dominates in the interviews: 'a lot of potential there in terms of energy extraction' (P17). Sometimes, the power of waves can be viewed not as constructive but destructive, that can do harm to devices (WECs): 'large amount of energy in the sea which isn't ideal for the

[165] A technical term used in the discourse referring to resource assessment of the total potential wave energy at a particular location, typically ahead of a wave energy development.
[166] Clarifications of the terms and notions used in expert discourse are not always readily available if we want to dig in the content of scientific work

industry at the early stages because it makes everything a lot more challenging.' (P17) A typology of waves, that some of the respondents operate, is applied for a particular purpose. It helps to formalise a discourse around the destructive power of waves and the potential threat for wave energy converters framing the phenomenon as a measurable object and making it available for scientific analysis. When discussing 'extreme waves', the participants call them 'one in ten year wave', 'one in fifty year wave', which is, in participants' view, statistically the largest wave that might occur once in a ten-year period, or once in a fifty-year period. (P17) The ability to predict such waves, as well as an ability to make predictions on the ongoing basis for the Wave Hub site, is seen as one of the primary tasks for the scientists working on resource assessment; it transmits the expert knowledge of the scientists into practical domain and makes it useful for wave energy industry. At the same time, it becomes a significant factor that device developers have to consider when designing their machines.

For characteristic of waves from the point of the potential for energy extraction and for coupling with a particular location the aggregative term 'wave climate' is used: 'There is nothing desperately unique about Wave Hub in terms of wave climate. <...> it's good wave climate, it isn't too extreme compare with west coast Portugal, for example, west coast Ireland.. the waves are more extreme.'

Describing waves as a source of energy, the interviewees point to the biggest problem with wave energy – 'sporadicness' of power and its seasonal character: 'you don't have any source of constant resource and it's so seasonal.. you can have this quite large resource in the winter and then it drops right off in the summer. <...> one of the problems for the wave industry, if you want, to actually develop to the sizeable industry is how you deal with this sporadicness of the power.' (P17) This is one of the key questions addressed by scientists and described in the studies for particular regions or sites: 'The average wave power at Wave Hub is approximately 20 kW/m. The wave power varies with time, wave direction and space. As can be expected, the wave power is largest in the winter months with mean values of 40 kW/m and lowest in summer with mean values of 10 kW/m.' (van Nieuwkoop et al., 2013, p.13).

It is noteworthy that waves are framed in this scientific discourse as a measurable object. This became evident when it was referred to and described by some of the participants in the light of conflict with the surfing community (arising from the siting of Wave Hub).

Waves as an object of expertise appear in a discourse about possible 'wave reduction' as a result of the impact that Wave Hub might have on shoreline wave height. The controversy between project developers and one of the powerful stakeholders – surfers was discussed in detail earlier in the thesis. Apparently, the potential impact on shoreline waves became a source of concern for the surfing community and surf industry. A number of studies were prepared by various experts to calculate the potential impact;[167] sets of models were produced 'to reflect wave behaviour off Cornwall' (Connor, 2007). The figures presented by different experts regarding wave height reduction were referred to as 'often-conflicting' (ibid.). The important feature of this discourse is that the figures were hypothetical and represented speculation and expectations about the possible height reduction, without practical evidence. That is, basically all of the extant data came from assumption based theoretical models. It is argued that there is a general lack of evidence based data available in the sector due to the low levels of deployment of WECs. It is noteworthy, that the scientific and policy communities operate with the assumption that sufficient evidence or data can be collected to inform policy based on theoretical models.

Wave measurements are also seen as data of high value for device developers (Phillips et al., 2008). For this purpose, special equipment installed offshore – 'buoys' (floating data gathering and recording technology) perform as key measuring instruments used by scientists to, in Anne Beaulieu's terms, 'gather added value in virtue of their being mobilized in a Latourian sense, while quantification, analysis and evaluation of data, accomplished automatically, are taken to guarantee their integrity

[167] SWRDA, 2006. *Wave Hub Development and Design Phase: Coastal Processes Study Report*. Exeter.
Millar, D., Smith, H., Reeve, D., 2007. Modelling Analysis of the Sensitivity of Shoreline Change to a Wave Farm. *Ocean Engineering*, 35, 884-901.
Black, K., 2007. *Review of Wave Hub Technical Studies: Impacts on inshore surfing beaches*. Exeter: SWRDA.

as data.' (Beulieu, 2001, p.665). The buoys might be seen as communication devices for scientists in their interaction with waves delivering data for 'real time operational model'.

"Wave data" in scientific discourse turns out to be shorthand for scientific means, tools, and practices to achieve credible abstraction, measurement and modelling of wave energy resources which can be used in justifying the installation of a wave energy testing site in a particular place or for rejecting it (Simakova & Iskandarova, 2012). It is also suggested that an understanding of wave energy characteristics of a location can be important in assessing the economic potential of wave energy projects in future and economic value that can be generated.

Statistical analysis as a way to organise and present data is used for Wave Hub sea state characterisation (Smith et al., 2012). Statistical understandings of waves play an important role: energy extracting devices need to be able to survive 'extreme waves', 'one in ten year wave', or 'one in fifty year waves' (Simakova & Iskandarova, 2012). As a result of long-term resource assessment the latest statistical description of a phenomenon is presented as following: 'For a 1/100 year event the significant wave height at Wave Hub is 9.6 m with 95% confidence levels between 8.6 and 13.9 m' (van Nieuwkoop et al., 2013, p.13). The specific wave characteristics, important for scientists, such as Wave parameters, (deviation of) Wave Height, Wave (or Energy) Period, Wave Power Density, inter-annual resource variability/variations (see, for example, Phillips et al, 2008), are all quantitative.

In the controversies over project location, assumptions about 'practical' data availability, the quality and sufficiency of theoretical models play an important role. It is believed that the generation of 'real world' resource data for a location can be used to refine theoretical wave models both specific to the site and more generally, with a view to their general improvement. The use of 'numerical wave models' (Smith et al., 2012, van Nieuwkoop et al., 2013) and relevant methodologies are often discussed in the literature, and in particular, in relation to Wave Hub site. It implies building representations of waves (wave behaviour) as an abstraction using some of the measurable properties which seem to be important for scientists. Generally, models are held to be less complicated than ‘real world’ objects representing various forms of simplification and idealisation of reality.

In experts’ opinion, ‘an operational wave model’ presents ‘highly accurate predictions’ and is needed because ‘conventional forecasting tools can’t predict conditions at the river mouth with sufficient accuracy’ (Smith, 2010b). It is claimed that it can be used by experts to gain a detailed understanding of the regional and local wave climate; to provide accurate data for devices deployed at the Wave Hub site; to provide real-time data to support marine operations from Hayle and other locations (ibid.).

Scientists produce various types of wave models. For example, it is suggested that in the case of Wave Hub there is a need to have regional and local models. To produce regional and local models different input data is used: for regional model wave and wind fields are supplied on a 24-hr basis by the Met Office; for local model input data comes from the PRIMaRE wave buoy array (ibid.).

The approach undertaken by scientists towards the study of waves is supported by statistical and quantitative logic. It indicates that for scientists (and the general public) it is seen as fully legitimate to deal with a conflict over resources (waves) by means of measurements and modelling that hypothesises possible wave behaviour. Within official discourse, this is perceived as the only reliable and acceptable way to understand and describe the processes in the sea.

In some sense, technoscientific understanding of waves based on ‘singularisation’ (as in Callon et al., 2001) and abstraction, makes it a resource by virtue of practice, providing grounds for operating wave as a ‘good’ in future economic exchange (Simakova and Iskandarova, 2012).[168]

Another powerful tool for describing waves in scientific discourse is visualisation which often becomes a form of data analysis and interpretation. I began to discuss visualisation in relation to Wave Hub in the previous chapter. Here I will consider particular visualisation of wave as part of scientific discourse in relation to expertise.

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[168] See figures 12-15 as examples of visual singularisation and abstraction of wave in science.

It is suggested in STS literature that images in scientific representation practice should be regarded 'as essential and substantive contributors to science' (Gross and Louson, 2012) and can be seen more than merely frills of summaries but also as 'foci for modes of thought' (Gould, 1992, p.171). Scientists use the images not merely to represent the 'truth' (or 'real world systems'), but also to make claims and communicate the ideas and theories.

The visual images, used in scientific discourse in regard to waves and wave energy, represent a way of practising scientific visualisation. Moreover, they represent a mode of objectivity accepted and constituted for this field of expertise.

Most of the images used by scientists represent numerical models and can perform as model descriptions. In this sense, the visual images can be readable – they reveal or display the relevant data to experts. Although it is believed that the images are 'simplifications' of models and far less rich than models themselves, as a rule, the images are also subjected to extensive analysis in order to interpret and make a conclusion.

For scientists the use of computer graphics and scientific visualisation software are important tools to organise knowledge about the object (wave), which also contribute in pursuit of 'digital objectivity' (Beaulieu, 2001) in relation to the object. It can be suggested that the use of digital technologies and computer programmes resulted in new ways of seeing objects (e.g. waves). The common visualisation practice is represented by various diagrams (figures 12-15) and maps (atlases) which illustrate the specific properties of particular geographical areas (or even the world) (figures 16-18). As such, wave visualisation entails elaborating digital means to show the existence of energy resources and the "sea state" (Simakova & Iskandarova, 2012).

Fig. 12. Variation of directional distribution of incident wave energy with *m* and DSPR[169]

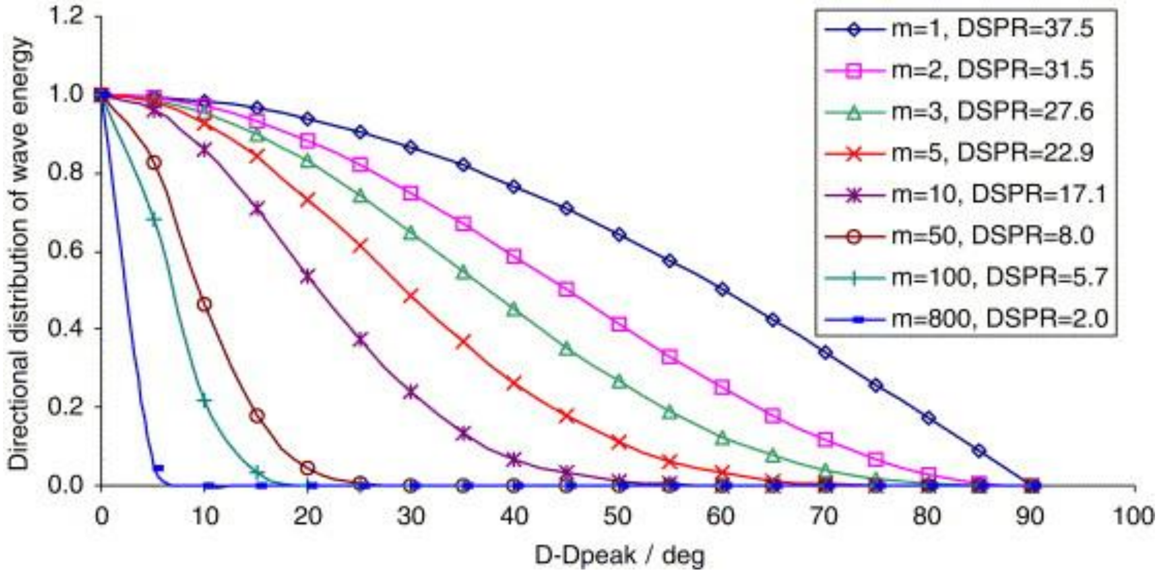
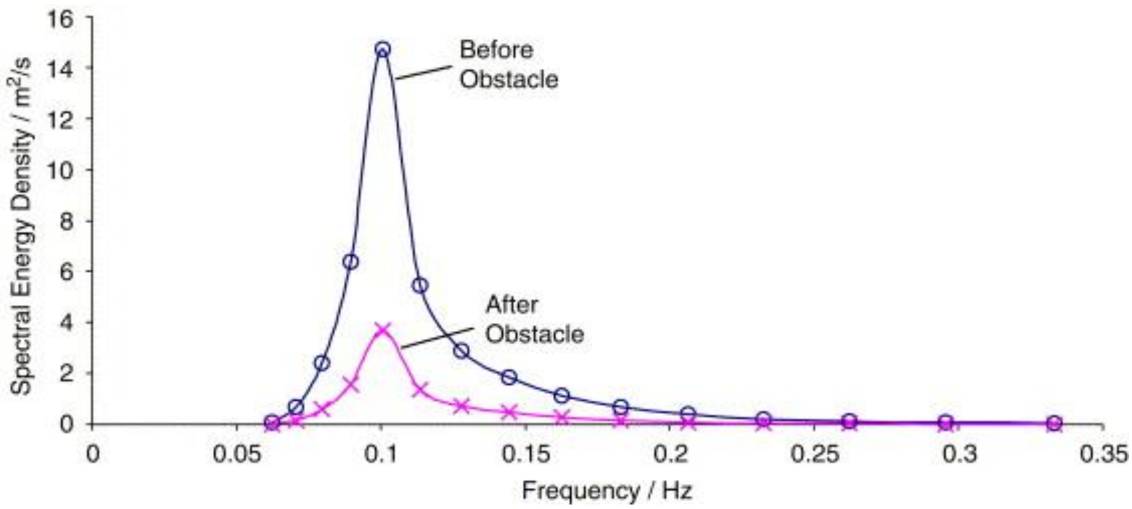


Fig. 13. Comparison of wave energy density spectrum before and after passing through partially transmitting obstacle with a transmission coefficient of 0.5[170]



[169] Source: Millar, D., Smith, H., Reeve, D. (2007).
[170] Source: Millar, D., Smith, H., Reeve, D. (2007).

Fig. 14. Wave buoy array data[171]

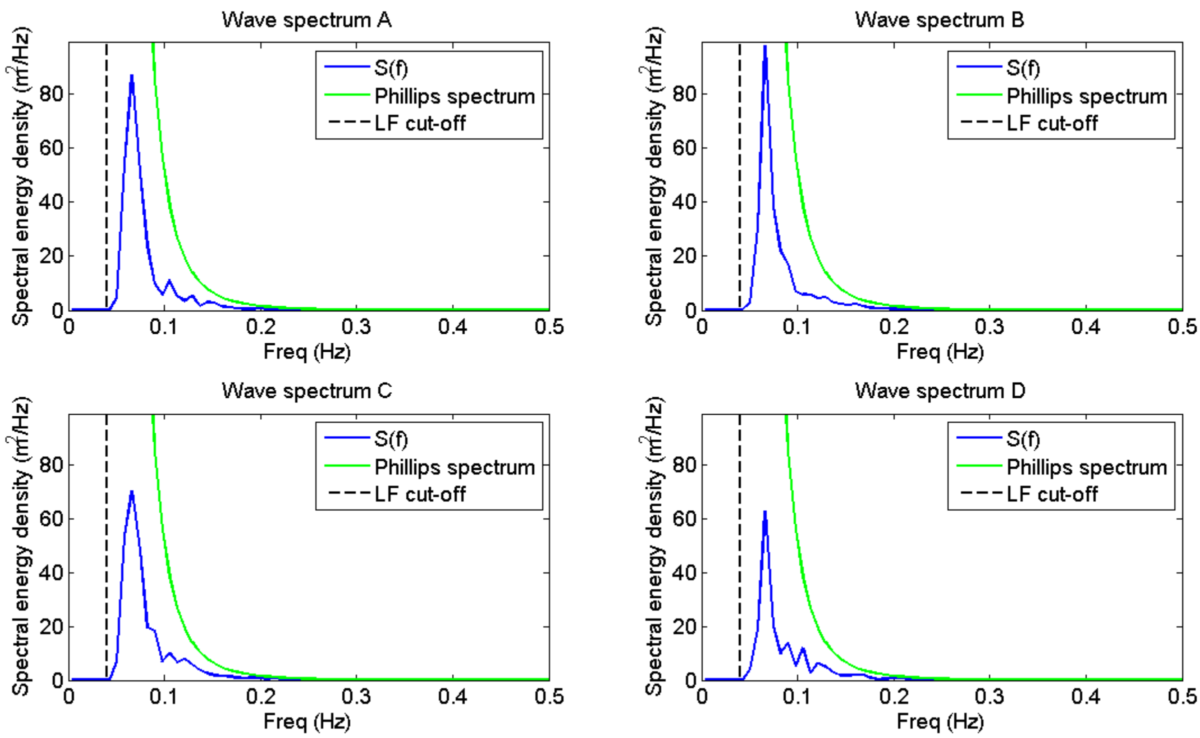
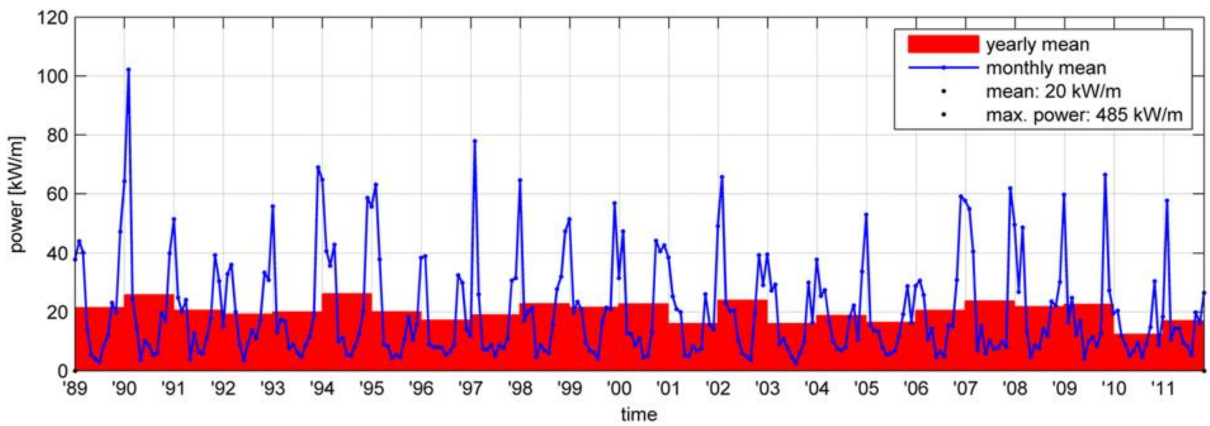


Fig. 15. Monthly and yearly power variation at location 1, Wave Hub[172]



[171] Source: Smith (2010).
[172] Source: van Nieuwkoop, J. et al. (2013).

Fig. 16. Overview mean wave power on the Cornish coast with bathymetry contours[173]

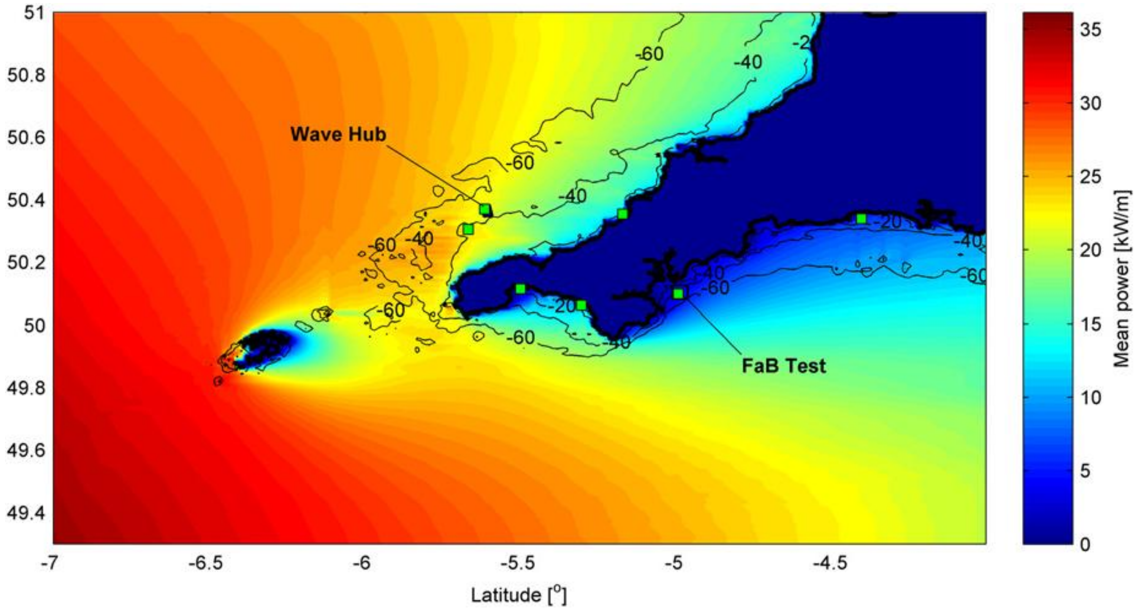
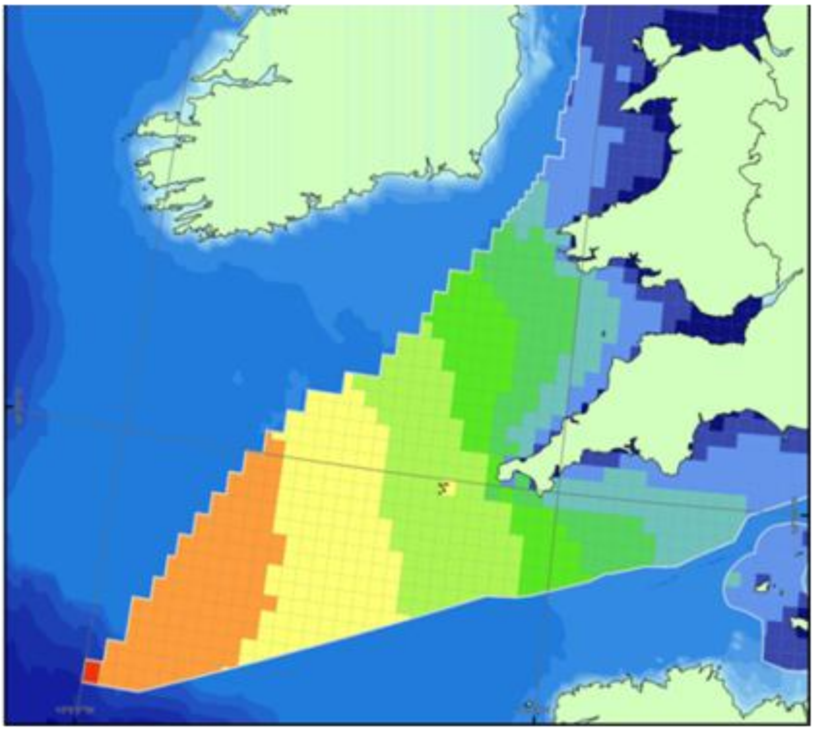
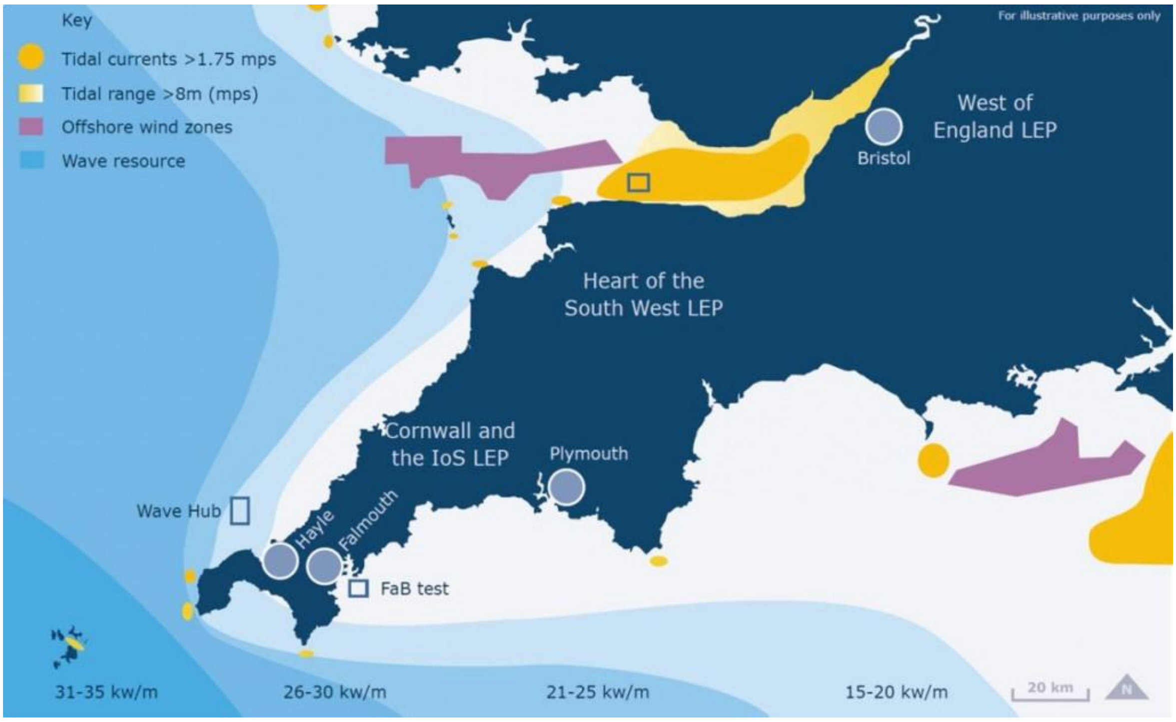


Fig. 17. South West Wave Energy Resources[174]



[173] Source: van Nieuwkoop, J. et al. (2013)
[174] Source: Atlas of UK Marine Renewable Energy Resources. 2008.

Fig. 18. Offshore Energy Resources in the South West[175]



7.3. Categorisation of expertise as a membership device

7.3.1. Different types of expertise: academic, commercial and managerial

A common theme in the discourse appeared to be a division of expertise (and a division between the participants on the ground of expertise), its categorisation and contradistinction of expertise possessed by different groups.

Different categories of expertise arise from the institutional setting and bureaucratic landscape, different work practices, and can be political in character (have a political dimension). It also represents a mode of membership for the participants and influences their position on all sorts of questions in the interviews and often leads to conflicts between the accounts.

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[175] Source: Wave Hub. 26 July 2012. *Shaping the future strategy for marine energy expansion in the South West*.

For the participants who position themselves as experts the affiliation with a particular organisation was important in terms of sustaining their expert status. In their eyes, such affiliation or ‘membership’ can give more weight to their statements, becoming a representational issue (symbolical).

The participants presented the project as requiring different types of expertise for its fulfilment. As any technological project, it highly dependent not only on engineering expertise, but involves managerial and scientific expertise.

The organisational and political dimensions of categorisation were the most interesting for me as a researcher. The former represents organisational arrangements, the allocation and definition of roles, and symbolic boundaries (e.g. Universities of Exeter and Plymouth) which also can be political, and coding of expertise. The latter allows the participants to position themselves in relation to others, to avoid situations that can undermine their status, to moderate the impression. It also allows criticism of other expert groups and their work. As an example, the fact that one of the groups of academics did not provide support to this research project, despite being a part of PRIMaRE, was seen as politically incorrect by other academics. The political dimension can also incorporate an ethical element when certain behaviour can be presented as inappropriate.

The respondents operate with different types of categorisation of expertise. Categorisation based on discipline was typical for academics talking about themselves. Categorisation based on the organisational and affiliation principle (‘functional’) is another way by which experts draw boundaries between themselves. Reputation-based expertise (e.g. Halcrow, JP Kenny) is contrasted with local expertise (e.g. Mojo Maritime), ‘real’ expertise’ – with ‘garage’ expertise.

The interviews revealed that the participants rely on three main categories of expertise based on the organisational affiliation, namely managerial, commercial and academic expertise. The first is mainly associated with SWRDA and the managers of Wave Hub, the second category is represented by various consultants and in-house expertise of the companies, and the universities and PRIMaRE embody the third. There can be some overlap when, for instance, the academics participate in commercial projects and perform consultancy work for device developers.

The RDAs, which were non-departmental public bodies, promoted the economic development of the regions and were expected to contribute to the policy in different areas such as transport, education, public health etc.[176] The participants share the view that SWRDA did not possess any specific expertise in relation to marine renewable energy.

Giving credit to SWRDA for completing an ‘enormously complex thing’, the representatives of the academic community express a lot of criticism in regard to managerial expertise (the choice of consultants and managers) and a lack of proper ‘marine renewables’ expertise in the hierarchy.

Appealing to common sense, the participants willingly discussed what SWRDA have done and what they should have done. It implies that SWRDA’s expertise (managerial) is seen as transparent and that it can be subject to the scrutiny of outsiders (anyone who is familiar with the case). It seems that the access to inner information that some of the participants have in regard to the progress of the project (through their participation in the meetings and other collaboration activities), beside the general information publicly available, as well as personal contacts with the management team, facilitated the creation of understanding of the project development and managerial practices employed by SWRDA. (The vision of SWRDA’s expertise based on this information was circulated in some communities (i.e. PRIMaRE).)

Despite sharp criticism expressed by some of the participants, officially the success of Wave Hub is linked with paying tribute to ‘an excellent team at the RDA’ and contractors.[177]

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[176] Regional Development Agencies http://www.politics.co.uk/reference/regional-development-agencies

[177] PRIMaRE news. *Wave Hub wins national sustainability award*. http://www.primare.org/index.php?p=106&id=99

7.3.2. The politics of commercial expertise

The important feature of Wave Hub is that external expertise was brought in deliberately by SWRDA. The group of consultants and other experts who had contractual arrangements with SWRDA (e.g. a managing company) can be labelled as 'commercial expertise'. This includes not only Halcrow group (an engineering consultancy) and JP Kenny (an engineering and management contractor), but their subcontractors, such as GL Garrad Hassan[178] ('independent renewable energy consultancy'), who performed an economic appraisal, or Arthur D. Little[179], an international management consulting firm, which prepared the business case. Therefore, a complex network of experts was involved.

As suggested by Martin (2008-2009), the work of hired experts serves the interests of employers, and as such is not neutral but political. In case of Wave Hub the various consultants brought in by SWRDA were intended to meet SWRDA's needs and expectations in regard to the project. SWRDA's desire to have a renewable energy project that would look innovative set a vector for their work, and sometimes, particular tasks to fulfil. Although some of the experts did not have experience in this kind of project (e.g. the consultancy: 'we had to find our way through that for the first time, that's why it took quite a long time'), the attitude to unknown tasks reflects the specificity of commercial expertise – such tasks are seen as a way to gain new experience and learn more about the area since they perform as practitioners, not scientists ('can-do' attitude).

It is also political in terms of self-representation of experts and the marketing strategies they use to be employed by a client. As suggested in the literature, 'the biggest thing going for the experts is that they are thought to be the experts' (Martin, 1991, p.9). For SWRDA, reputation-based expertise of the companies they hired became especially important at some point when they faced a dilemma of changing one company (consultancy) to another.

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[178] http://www.gl-garradhassan.com/en/aboutus.php
[179] http://www.adlittle.co.uk/

The companies, which represented this group of experts, admitted their status as commercial experts using the rules of market and corresponding terminology. As such, one of the participants characterised the way the company became involved from the point of good marketing and personal communication: 'I think we did a good sales job on them [SWRDA] at some set. Our Managing Director knew some people there... through business development and networking I think the opportunity to support them and we got them a proposal which they quite liked'.

As a result of the recognition of their expert status, the 'business as usual' practice employed by JP Kenny (an engineering and management contractor) was not challenged, although they admit the difficulties and some mistakes. It would be safe to suggest that there was no one in a position to challenge them and it was not clear how to measure reliability of the practices they applied.

The interviewees who represented this group of experts were capable, using Lynch and Coles' wording, of acknowledging circumstantial and practical limits to the knowledge and experience they possess, when explaining the situations that are seen by others as 'failures' or 'mistakes' (Lynch and Cole, 2005, p.288).

The wide critique of the group of commercial experts and their work was an important theme for my participants; it needs to be considered in more detail and will be a subject of a discussion later in this chapter.

The involvement of researchers and scientists in the case of Wave Hub was deliberate in order to provide academic expertise and to make the project attractive to device developers. The conception of Wave Hub as an entity closely linked with academia increased its chances to be perceived as a credible scientific endeavour. Inevitably, the academics became active participants, positioning themselves as experts; their claims to expertise are not contested by others. They form a group mainly associated with a research institute – PRIMaRE which will be examined in more detail.

7.4. The production of academic expertise around Wave Hub

7.4.1. PRIMaRE as a 'boundary organisation'

My approach to analysis of data in relation to one of the key actors – PRIMaRE, as a research institution founded in support of Wave Hub and funded by SWRDA and EU, is inspired by the work of Gieryn (1983), Guston (2000, 2001) and some others who developed two interrelated concepts of 'boundary work' and 'boundary organization'. This approach allows me to examine how this university-based boundary organisation succeeds, what are the challenges they face, what stand behind boundary management decisions and how they are made in complex dynamic environment.

The concept of boundary organisations is based on the idea of 'boundary work' (Gieryn, 1983) which implies that the demarcation between science and nonscience (fraud, pseudo-science) is a result of a strategic behaviour and contingent circumstances rather than essential characteristics or methods. When the organisation serves as a 'boundary object' (Star and Griesemer, 1989), i.e. crosses the gap between different social worlds (e.g. science and politics), it can be seen as a boundary organisation (Guston, 2001). The criteria of such organisations, according to Guston (2000), besides being at the frontier between relatively different social worlds, includes distinct line of accountability to both worlds – of politics and science. Comparing to other concepts (e.g. boundary objects), the concept of boundary organisations is introduced as a 'rout to stabilization', as they can straddle the science-politics boundary internalising the boundary negotiations ('the provisional and ambiguous character of that boundary' through constant negotiation process) (ibid., p.30).

The analytical framework of the concept is formed by the principal-agent theory (Guston, 2000). This analytical method is suggested for analysis of science-policy interactions from the contractual point of view, where the government is understood as a principal[180] and science as an agent who performs the delegated tasks on request of the principal (Guston, 2000). Conceptually, a constructivist approach to understanding the problem of boundaries between science and politics can provide 'the close, empirical, reasoned, and unvarnished account of scientific work' (ibid., p.16). It is based on the idea that science has a social component and influenced by various social factors and organisational, technological processes of knowledge creation.[181]

Some conceptual and methodological amendments have been suggested in relation to university-based boundary organisations. According to Parker and Crona (2012), the specificity of such organisations is that academic, political and industrial activities usually overlap ('hybrid space'), making it difficult to separate two groups of principals with distinctive positions in political and scientific community. Moreover, this type of organisation serves not only two constituents, as in the traditional understanding of boundary organisations, but several different constituents ('more complex arrays of constituents' which they call 'heterogeneous stakeholder groups'). Thus, the bilateral approach of principal-agent theory is not sufficient and needs to be adapted to these situations. To address the complexity of accountability of university-based boundary organisations the stakeholder perspective was suggested to be used to complement the key concept (ibid.). Equivalent accountability is also questioned. Parker and Crona (2012) discuss 'skewed accountability' which has particular relevance in situations where some of stakeholders can influence the agenda more than others. Analysing boundary management as a process rather than an act ('continuous process of negotiating multiple tensions'), reconsidering the temporary dimensions of boundary management and the strategic decision-making about internal working and structure of a boundary organisation, they consider external and internal forms of its management (ibid.).

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[180] By the principal Guston means the government 'who requests the agent – science – to perform certain tasks because the principal is not capable of performing them directly' (Guston, 2000, p.15) (principal – agent view of science policy).

[181] In the literature review the reference to the debate in STS about politics in and of science was made.

My analysis is in agreement with the suggestion that universities can be viewed as a place to house boundary organisations. In the case of Wave Hub the involvement of the University of Exeter and the University of Plymouth was a deliberate decision. The Peninsula Research Institute for Marine Renewable Energy (PRIMaRE), created as a 'centre of excellence delivering world-class research and technology transfer in marine energy', can be understood and analysed as a boundary organisation.

It was designed to manage the meeting of different areas of expertise and to encourage the effective collaboration between the universities, as well as with industry. As any boundary organisation, it operates 'at the interface between knowledge and application' (Guston, 2001) conducting research for basic and applied purposes.

Developing a concept of Wave Hub, the RDA considered the universities as 'stakeholders'[182] which meant their interests needed to be 'aligned' for the overall success of the project with the task to coordinate academic efforts to support Wave Hub.

The early policy renditions of Wave Hub featured a familiar theme of translating basic science into technological outcomes. The idea of having funding in place for PRIMaRE, coming from SWRDA and the European Union, looked attractive in the eyes of key stakeholders (SWRDA, the universities and device developers) and was without any criticism: it was called on to stimulate 'the creation of a whole new knowledge-based industry and related business opportunities for new marine low carbon devices, services and energy production in the South West'; in particular, it might have had the potential to attract professionals interested in marine renewable energy and 'work in support of Wave Hub', it would make the site attractive for device developers as the purchased equipment (e.g. buoys) was very useful 'in order to do the basic science or the engineering and other activities to support the development.' In other words, 'the equipment could be not only used for research purposes but might also be used for consultancy'.

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[182] A term borrowed from policy studies standing for communities who are involved and/or have an interest in the project.

A lack of satisfaction in regard to consultancy work done for Wave Hub also played its role: 'In terms of PRIMaRE what we wanted to do initially was to do some baseline work.. some baseline research as there been a certain amount of criticism of some early research that consultancy done on behalf of RDA which have in our view insufficient rigour...'

The official description of the institute and its role emphasises its dual purpose: 'The Peninsula Research Institute for Marine Renewable Energy (PRIMaRE) is a joint venture between the Universities of Plymouth and Exeter with funding from the South West Regional Development Agency and the European Union through its Convergence[183] and Competitiveness[184] programmes. The Institute brings together a team of researchers to provide expertise and capacity to cooperate on interdisciplinary research, *addressing both close to market and fundamental issues* of relevance to the marine renewable energy sector' (emphasis added).

PRIMaRE's research activities, according to the official information, illustrate the idea of meeting of different areas of expertise and include: Environmental and Biodiversity Impacts; Resource Characterisation; Marine Operations; Safe Operations and Navigational Risks; Marine Electrical Systems; Socio-Economic Factors,[185] thereby covering not only different areas of expertise but also different approaches such as natural and social sciences.

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[183] Convergence is the new European economic regeneration programme for Cornwall and the Isles of Scilly that runs until 2013. Convergence is investing in activities that will have a long-term impact on the economy of Cornwall and the Isles of Scilly. It will help to build a stronger more diverse economy by supporting businesses and helping people into employment and those in work gain new and up to date skills. This will include work with higher education to promote business friendly research and innovation. (Convergence for economic transformation. What is Convergence. http://www.convergencecornwall.com/what-is-convergence/).

[184] European investment for the South West, outside Cornwall and the Isles of Scilly where the Convergence Programmes operates, is from the European Regional Development Fund (ERDF) Competitiveness Programme for the South West and the national European Social Fund (ESF) Programme. (Convergence for economic transformation. Competitiveness Programme. http://www.convergencecornwall.com/what-is-convergence/competitiveness-programme.php).

The South West Competitiveness Programme aims to increase the prosperity of the region by supporting enterprises and individuals in delivering projects which drive up productivity and competitiveness.

[185] PRIMaRE. *Statement of research activity and capability*.
http://www.primare.org/resources/files/PRIMaRE%20Cap%20Stat%20sp.pdf

Claims regarding value for industrial and economic development are the key arguments in the rhetoric surrounding the research entity. According to the official vision, PRIMaRE was founded not only to support Wave Hub, but also to accelerate growth in the marine renewable energy industry and to help the South-West to become a region of international significance in terms of marine energy.

To demonstrate the creation and transferrence of usable knowledge is an important task for the research institution. It was accepted as undisputable by the members of PRIMaRE that the purpose of the investment ('a large payment into both of the universities') is a payment *to generate a knowledge economy* around renewable energy.

Boundary management is understood as a process of managing relations among stakeholders, and the structure and inner workings of organisations (Parker and Crona, 2012). In case of PRIMaRE the issues related to boundary management (or rather practical management of boundaries) and related tensions include the relations between two universities, the continuous construction of the boundary between academic and commercial expertise (autonomy and consultancy), the negotiation of the interrelations with Wave Hub and the industry, the tensions around intellectual property and some others. The participants have to continually negotiate those various management tensions. While the policy community (e.g. funding bodies) desires applied research, the academic community values basic contribution to their discipline higher and see themselves as academic scientists first rather than researchers doing consultancy work for the industry.

PRIMaRE's structure has several important characteristics that are crucial to understanding how the organisation operates, e.g. funding, management board, two universities involved, expertise coming from a range of disciplines; inner structure and hierarchy – 'senior', 'named' researchers *vs.* young researchers at beginning of their career who do 'all the work'.

To sum up, the institute was described in several ways: a partnership for two universities, a bridge between universities and industry, an interactive network and actor/agent, a hub of knowledge and expertise. The participants also saw it as a ‘quasi-institute’ – ‘It’s a quasi-institute really; there’s no building; <...> a name for an organisational group of people’.

The problem of collaborations between the two universities and their relations with the industry were the main focus of attention when the participants discussed PRIMaRE and its activities.

The analysis of data reveals some tensions between the universities although each university has a separate funding for its research activities. There were ongoing attempts to divide the areas of research between them. This issue seems to be important for the respondents, and in several interviews the line was variously drawn.

‘The wave research <...> one of the big things we decided to look at here [University of Exeter], along with the moorings <...> and the electrical power grid integration side of things as well. Well, as Plymouth went more down the route of looking at device hydrodynamics, the actual movements of the device and interaction of the devices with the waves rather than the actual resource assessment.. and also the coastal affects – so how Wave Hub might impact on coastal processes.. whether it might change the beaches, impact on the shoreline and that sort of thing.’

The certain degree of imbalance between the universities in terms of scale of research and its quality (level of expertise) was felt when the representatives of Exeter were comparing their work with the work done by their colleagues in Plymouth. The degree of criticism varies among Exeter academics. A version of explanation for work imbalance was provided by one of the PRIMaRE’s researchers who has good working relations with the colleagues in Plymouth University: ‘that is one problem with the PRIMaRE collaboration …it feels a bit like we’re doing all of the work, whereas in fact we probably are because we’re geographically a lot closer and that isn’t that Plymouth can’t do the work, it’s just that they’re 100 miles up the road. It’s a lot and logistics is the biggest problem in all of this stuff or I perceive that to be the case.’

Nevertheless, the respondents cooperate or see the potential for cooperation with the researchers from the other university: ‘Plymouth has bought a certain amount of equipment as well.. one thing they've invested in is something called an HFradar system – high frequency radar. <...> It's not as accurate but there is a lot of potential for doing research looking at comparing the radar results with the buoy results. So that's really Plymouth's piece of kit in the buoys. So we both are going to be doing a lot of research in this area but most of it's gonna be done here, I think.'

In the quote below, a participant talks about his experience of working together with colleagues from another university. The characterisation of collaboration as working together (not competing) is underpinned by understanding of their expertise as being focused on different areas of the sea: '...we work together but we don't really compete. Plymouth is a very strong laboratory university on benthic ecology – seabed ecology – that is their field. We're much more stronger in the whole pelagic, you-know, dolphins, porpoises, basking sharks and sea birds – that's very much our remit, not theirs – so we don't really conflict because I'm not desperately trying to be a seabed ecologist and they're not trying to be pelagic ecologists. Or, if we are, neither of us are telling each other. <...> we just work really well together – but I think it's because we're young and enthusiastic really. <...> we wrote a paper for The Royal Society and that was a collaborative paper. <...> It's all very rosy between us but I don't think it is in other sectors.'

To make sure that both universities collaborate effectively, funding is being spent wisely, 'research got on the way' a position of an independent chairman was established. The incorporation of an independent chair in its decision-making structure (PRIMaRE board) had the aim to achieve a balance between two universities.

Wave Hub is an example of what Jasanoff (2004) calls 'co-production of knowledge and social order'. The involvement of PRIMaRE as a boundary organisation in co-production, i.e. the simultaneous production of knowledge and social order, is characterised by collaboration with the companies – device developers and creation of 'scientific and social order' (Guston, 2001) by means of boundary objects (e.g. reports, various data, or research programmes).

As suggested by Guston (2001), the boundaries and stability of such organisations are drawn through 'being accountable and responsive to opposing, external authorities' (Guston, 2001, p.402). Empirical research shows how it happens in specific cases. I also came across a discussion about accountability, but surprisingly for the participants some of them were not asked for official reports to the funding bodies (i.e. SWRDA) at the time of data collection. 'I'm always hugely open to doing stuff for them but they've never engaged with us at all really which would surprise me, given that they paid all this money. My only concern is that I don't think SWRDA have made good enough use of us; they've given us all of this money – which is brilliant – but I would like to have thought that they would have engaged with the environment work much more and they haven't.'. As such, PRIMaRE's external accountability is reflected in and mediated mostly by its collaboration with the wave energy industry and the outcomes of such collaboration.

7.4.2. Collaboration and commercialisation of scientific knowledge

As with other techno-scientific initiatives, wave energy projects are not exempt from rhetoric of industrial collaboration demanded by policy, to which universities feel they have to respond.

PRIMaRE is accountable externally to its funding bodies. SWRDA as a funding body and the founder (main principal) judged the success of the research institution through its effective collaboration with the companies.

It is emphasised that the PRIMaRE concept was developed as a research entity linked to Wave Hub which would be capable of supporting the companies coming to Wave Hub with research and expertise: '..they felt that there should be some research infrastructure created in this area. And the idea of PRIMaRE was to be a catalyst for the developments of a *research base and a consultancy base* to enable developers to come down and use Wave Hub with confidence knowing that they would have the support for everything else that they needed, certainly from engineering and science point of view.'[186]

[186] The obligations for the University of Exeter to form links with local industry are also part of other funding streams (e.g. Convergence Programme).

Therefore, the members of the academic community were exposed to the need to organise collaboration with the industry in accordance with the purposes of the research institution and intentions of the funding bodies. The idea of university – industry interaction was portrayed as a matter of practical necessity (‘a matter of practical and strategic concern’ (Simakova, 2011, p.14))[187].

It is worth noting that collaboration as a policy metaphor was explored in literature, in particular in relation to nano technologies (Simakova, 2011), where university-industry collaboration as an element of the discourse and operations of a scientific department was analysed. As with existing research on collaboration (e.g. Simakova, 2011), this chapter does not undermine the value of collaboration. Instead, perceiving it as a ‘powerful device’ (ibid.) I will try to explore its role in the Wave Hub case.

The participants pay special attention to activities and actors involved in collaboration, and despite some secrecy and sometimes anonymity (in regard to the companies), willingly talk about the collaboration process, allowing some criticism regarding their technologies, external experts and other companies in the sector. The very idea of collaboration is not an abstraction for them and does not pose any ambiguity (or at least was not shown in the interviews) – it assumed a form of particular projects and contracts and closely tightened with the additional funding opportunities, being ‘fairly streamlined’.

The commercial application of the research performed by PRIMaRE is seen as a desirable outcome by the funding bodies and a measure of its success. ‘...It is gratifying to see the commercial application of this research. The innovation of PRIMaRE is already developing a stronger supply chain in this emerging area of the economy for local and national businesses. It is through investment in top quality

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[187] Although the comparison between nano and wave energy seems too distant, wave energy rhetoric similarly incorporates industrial collaboration as a matter of practical necessity.

applied scientific research and knowledge transfer to businesses that we will successfully tap these new markets, and it is inspiring to see this happening.'[188]

According to the members of PRIMaRE's board, SWRDA is highly satisfied with their work: 'it was pleasant to see that one of the comments from the RDA was that PRIMaRE had gone much better than they have expected in terms of the output that they're gonna achieve.. it's far exceeded their expectation.'

The positive assessment of PRIMaRE's work by funding bodies (e.g. SWRDA) is important, as in case of boundary organisations the success is judged by principals on both sides of the boundary and based on its ability to provide them with necessary resources (Guston, 2000).

As it was elucidated, PRIMaRE collaborates with industry to support research and development activity across a number of areas, including; design, engineering, environmental impact and grid connection: 'what we're trying to do is to collaborate with businesses, wave device developers and other stakeholders reproducing the data in a format that faces their requirements.'

As an example of such collaboration, the participants refer to the Technology Strategy Board projects which are 'very applied and focused on commercial development'.

Collaboration with the industry is a way to address both 'close to market and fundamental issues of relevance'.[189] By way of illustration, the participants mention their work with two device developers based on the contractual arrangements. The TSB contracts, which are dependent on 'industry-academia partnership', allow the involvement of PRIMaRE[190]: 'We have various strands to that work.. with one of the

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[188] Carleen Kelemen, Director of the Convergence Partnership Office. PRIMaRE Case Study. Mojo Maritime Ltd. http://www.primare.org/resources/files/PC%20Mojo%20Marine.pdf

[189] PRIMaRE. Research Areas. http://www.primare.org/?p=4

[190] For example: Technology Strategy Board - The funding allocated through a collaborative research and development funding competition designed to support innovation will lead to the cost effective exploitation of UK and global wave and tidal stream resources (one of the project is led by Fred Olsen Ltd. – lead organisation, others – consortium members). *Project Title:* BOLT-2-WAVEHUB *Partners:* Fred Olsen Limited (lead); Supacat Limited, Scotrenewables Ltd, University of Exeter *Description:* BOLT is the name of the Fred Olsen wave energy device which has undertaken sea trials since June 09. The BOLT-2-WAVEHUB collaborative project aims to integrate elements that will make truly pre-

device developers we're specifically working more closely with one than the other.. <...> So it's resource studies, it's environmental data, it's consenting, and there is small input from our team into the engineering of the device.. we have DMaC which is a large physical land based testing machine. DMaC stands for dynamic marine component testing. So we are going to test some of the mooring components for one of the devices on DMaC test rig.'

A board member depicts the work which is being done with the device developers as 'going the right direction'.

One of the scientists characterises the work done by PRIMaRE with device developers under TSB funded schemes as an 'enabling work', looking at the needs of the developers to help them to deploy their devices. 'Different researchers here are working together to kind of linking different areas of expertise.' As an example, the respondent talked about 'a road map' which was being produced for the company X at the time of the field work to deploy their device at Wave Hub site.

The scientists see their work as useful for the companies planning to install their devices at Wave Hub: '...we probably have the data that they need and they could shortcut their EAI [Environmental Impact Assessment] process by approaching us and asking for the data or buying data or working collaboratively with us, because most EIAs ask for about one or two pre-construction data, which, of course, they won't have but we will because we'll have already been there.'

Moreover, the senior academics are proud of their reputation, work they are doing and how it is valued by the industry: '...we're successful to getting device developers down here because they like work we are doing as academics, and they like to work with us together.. and we are trying our best in order to make sure that companies coming down here are installing at Wave Hub site.'

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commercial deployment at the Wave Hub site a reality. This will be achieved by reducing the production costs of wave energy converter units and by reducing the costs and risks of deployment, installation & retrieval processes of wave and tidal devices. (Technology Strategy Board. 23 July 2010. *Driving Innovation*. Press Release).

At the same time, they admit the obvious dependence of PRIMaRE's success on the availability of funding for the industry, political and financial mechanisms in place, and eventually, the success of Wave Hub. 'The issue for us is clearly if Wave Hub is not progressing, PRIMaRE itself will not progress as well, because we rely on device developers coming down here, doing research with us, installing at Wave Hub. Only at this point we become useful. We can try to push as much as we want, but we won't be able to bring the research down here anymore. <..> it's a 'marriage' between PRIMaRE and Wave Hub to some extent.. because we need Wave Hub.'

Complaining about the difficulties of bringing device developers to the South West, the participants talk about other places as more financially attractive – due to different ROCs and political engagements, device developers prefer Scotland, as the Scottish Government is seen as more committed to renewable energy at the time of my field work.

My research includes interviews with industry representatives who do not cooperate with PRIMaRE. In these interviews it was important to draw a boundary between industry and academia, presenting collaboration as problematic in terms of IP and interactions. The representative of one of the device developers characterises the collaboration with academia as difficult, arguing for having the best engineering knowledge of their wave energy device, as well as the best commercial knowledge of the industry, in-house. The dilution of intellectual property rights is also a serious concern: 'It's never been a particularly comfortable shoe to try and fit on the industry's technology collaboration between people like ourselves and an academia. There are other fields of research and development and collaboration which are less IP-sensitive and are probably more open for cross-collaboration between industry and academia, but technology tends to be quite a hard one to do.'

Some of the academics also have concerns in regard to effective collaboration and data sharing by the companies-device developers. It was suggested that since the devices are in the water, it could be problematic to access the 'commercial in confidence' data (e.g. environmental data) and to operate at the site of Wave Hub: 'the thing that hadn't occurred to me was that if they consider environmental data to be commercial in confidence, then will they allow us to still operate at the site, because if we collect environmental data that shows their devices to be problematic… So I don't quite know how it will pan-out really, whether a bullish developer will move into the site and say, 'no, you need to stop your work because we'll take it over, but we don't want you monitoring in an area where we're testing our equipment'.

For those members of the research institution, who did not have contractual arrangements with the companies at the time of data collection, these relations were expected to be mutually beneficial (the idea of profit for the universities), and it is not necessarily a purely commercial form: 'Money is useful but academic prowess is stronger. <...> We're not on a money grab – we don't really need the money to be quite honest although it would be nice.' (P8) So for some of them a form of collaboration with, for example, having an access to their devices in the water can be a better solution ('...it fundamentally interests me so that would be a really good, nice piece of collaborative work'). At the same time, certain pessimism was there: 'But getting environmental data out of wave energy developers for pieces of academic work, people have tried and it's been impossible.'

To value both basic and applied research, PRIMaRE documents call for producing both basic research (fundamental research) and consultancy or close to market research. Nevertheless, the participants give a preference to the research they are doing as academics ('fundamental research').

7.4.3. Data sharing at the boundary between academic and commercial worlds

The analysis of production of boundary objects is not always feasible due to the high degree of secrecy in relation to the PRIMaRE's work with the device developers.

The general assumption shared by the participants is that the knowledge is owned by the academic community who generates the knowledge, and is used for benefit of academic endeavour ('in terms of publications and other services'). As most of PRIMaRE's research is being publicly funded, the intention is to make it available to other stakeholders.

As the participants see it, data sharing and an access to the information and knowledge for the wider audience depend on a source of funding of a particular piece of research and the nature of a project. These issues are viewed as a ‘point of discussion’ for the senior academics and board members who have to continually negotiate the boundary and find compromises. The desire of the academics to ‘publish as much as possible of this information’ might in some cases be in conflict with the interests of the sponsors of other projects (‘further add-on projects’) that have additional funding, beyond the scope of the work funded by SWRDA and the EU.

The collaboration with industry is welcomed by the academics, but can pose some problems. One of the most sensitive areas related to expertise and technological development is intellectual property (IP) rights. The analysis of data reveals certain antagonism between academics and device developers around IP issues. ‘Around the activity of marine renewable energy you have in the centre the device and often there is *a lot of intellectual property related to the device which is jealously guarded by the developer*, and they don’t like the idea very often of academics being involved with their intellectual property’; ‘...the device developers are not interested to give all IP away to other companies.’ (emphasis added). This opinion is shared by most of university researchers and scientists.

As a representative of PRIMaRE characterises the situation with IP in companies in regard to their devices, and in particular, the problems the companies experience: ‘The device developers keep it very well guarded, they don’t let us know.. We only know by second hand and third hand information and conjecture.’ Nevertheless, the research community believes that they know the situation in the industry well despite the secrecy around the devices: ‘Device developers keep it very very guarded, even when you are in a research contract with them, they try to restrict what you know. What we do know is that all of the device developers including those who are not working with us at all still have problems with their power take off systems.. in terms of reliability and durability..’ Naming particular companies and admitting the second-hand nature of information, the participants characterise the situations around some devices as ‘failures’ pointing to the problems with power take off and mooring systems, e.g. ‘a poor failure.. a failure that should never have happened’.

The problem of intellectual property and commercially sensitive information are usually solved by means of a confidentiality agreement ('with NDAs and IPR arrangements')[191], which is required to regulate the relationship between a developer and a small group of academics involved in a collaborative project (a small group rather than PRIMaRE as a whole).

The problem of data sharing between device developers was also raised in the interviews. In the quote below the commercial advantages associated with data sharing are explained by marine energy being 'relatively small and immature industry'. 'There is some collaboration [between device developers]. They do have meetings amongst themselves because they recognise that marine energy is something that has to be solved.. <...> There is also a certain amount of movement of staff between one company and another <...> but the core of their devices and the things they learned as result development they keep pretty close. <...> Knowledge sharing on things that all need to know, but not knowledge sharing about anything which gives them a commercial advantage. <...> It's similar I think to other areas. I think the difference is that it's relatively small and immature industry from that point of view. So we are not talking about many thousands of people, we are talking about a few hundred people, so it's different.'

The sharing of data that PRIMaRE scientists obtained with the use of specially purchased equipment (e.g. buoys) is an ambiguous question, and at the time of interviewing there was a general vague understanding of the procedure. It was suggested that some of the data can be publicly available: 'As part of the contract with SWRDA and with PRIMaRE we are making a certain amount of the data available to the general public. So we are in a process of setting up a website, for example, where data form one of the four buoys is going to continually update chats and so on..'. Most of the data is to be specifically requested – by those who have an interest in Wave Hub (e.g. device developers and others involved in the Wave Hub project). In one participant's view, this form of data sharing might involve a 'cost element'. Considering the deployment of special equipment – four buoys as a

[191] The access to this type of documentation was restricted.

‘unique situation’ for collecting data, the researchers see it as desirable to charge the outsiders (e.g. researchers from other universities), as the cost of data collection in this case is high.

To sum up, the issues related to data sharing are multifaceted. They are inevitable in a discourse around collaboration, and as interview data shows, pose questions and being negotiated. More generally, making data publicly available is a part of a dialogue between policy and science.

7.5. The main antagonism? Academic versus commercial expertise

A thread running through the interviews repeatedly posed the question as to what counts as doing proper research for Wave Hub. The main source of criticism was the academic community: SWRDA was criticised for the lack of managerial expertise and overdependence on consultants, some device developers – for fragmental design and bad engineering practices, and the consultants – for the commercial character of expertise they possess and a lack of independence.

Surprisingly, the opinions of the academics are very similar, although a degree of critique can vary. The information they obtained and referred to in regard to Wave Hub was often second hand, but nevertheless, the critical appraisal of other stakeholders’ work was delivered in a confident manner using persuasive rhetoric. The generally adopted point of view was often repeated. Such unity in patterns of thoughts, its sincere acceptance can be an evidence of a dominant standpoint being elaborated within the community in regard of expertise and work done by the managers and consultants of different affiliation (SWRDA, Halcrow, JP Kenny).

The dominant narrative is given as a story, a story of managers and consultants which became a part of the repertoire in relation to Wave Hub. The academics transmit it, and the arguments are not challenged within the community. Here the analogy can be made with ‘folk theories’ which, being generally accepted, became a part of the repertoire current in a group or culture in general (Rip, 2006). The participants attempt to capture patterns in what is happening but ‘tend to short-circuit their analysis so as to serve their action perspective’ (ibid.).

It can be suggested that for the members of PRIMaRE sharing this story is one of the ways to define their own status and to remind about their presence within the community. People of the academic community share similar views not just about general issues, e.g. criticism of the outsiders, but also about their community, its boundaries and distinction from others, by e.g. labelling themselves as ‘honest academics’. As the boundary is permanently challenged, the academics have to constantly negotiate it by means of defining precisely their area of expertise, clarifying the boundaries of their work, talking about themselves as ‘honest academics’, ‘real science’, distinguishing from commercial experts and other non-academics.

The boundary between SWRDA’s expertise and commercial expertise (i.e. various consultants hired by SWRDA) sometimes seemed to be blurred to my participants. SWRDA and the consultants were often perceived as a single object of criticism, and in their critique the academics were accusing both for the same failures and mistakes (e.g. they specified ‘a transformer which bizarrely didn’t exist’). Nevertheless, it is possible to differentiate them by juxtaposing different accounts and analysing additional data in regard to the interviews, such as the scope of the interviews, the degree of detailing, the position of the participants, the access to various sources of information, the second-hand nature of the information, etc.

The degree of criticism varies from quite moderate statements (‘perhaps, in a few cases the expertise could have been greater’) to destructive criticism (‘a poor failure’; ‘that was just negligent <...> clearly it’s an error to specify a piece of kit that is not ready for use’).

It was surprising for me as a researcher, that the most robust and continually repeated argument – the novelty of the project, which the managers and consultants use to justify certain failures and mistakes – is scrutinised and criticised by the academic community. Being critical about the thesis that the novelty of the project can be an excuse for certain mistakes made, a representative of PRIMaRE suggested the development and construction of the project to be considered as a number of separate tasks. Some of them, like laying the cable, were characterised as 'routine'; an offshore connector ('a box on the end of the cable') was also seen as unproblematic: 'Well, that's an offshore connector, so there is nothing terribly new about that. So you just make sure you are dealing with companies that have proven track record, and I am sure that's fine.'

Blaming SWRDA for the lack of the 'core skills' and 'right people' within the organisation, the representative of PRIMaRE see the reliance, 'overdependence' on consultants as the biggest problem for the project. In the respondents' opinion, the consultants are overpaid and do not perform well enough, but present themselves as 'the only option'. The managerial culture in which consultants are regarded highly can lead to the lack of understanding and control over a project, and that, as one participant said, could be the key mistake for the managers (SWRDA) in the case of Wave Hub.

The inability to deal efficiently with local stakeholders, like fishermen, was also imputed to SWRDA ('They [fishermen] are still not happy.. very very unhappy.').

Thereby, the first point of criticism was the managerial expertise of SWRDA which is understood by the respondents as an ability to organise effectively the process of project development, and in particular, to hire qualified professionals for making initial critical decisions ('engineers, not financial people'), and be able to deal with different actors and social groups negotiating compromise decisions.

The criticism of the commercial expertise appeared even sharper. A lack of satisfaction with the work done by the consultants was one of the most discussed themes in the interviews with the representatives of the academic community. Here the focus of criticism was on Halcrow, a consultancy whose role in the Wave Hub development is perceived as crucial and was discussed earlier in the thesis. The concerns expressed by the respondents are related, first of all, to the level of detail in their work – the consultants were criticised for 'short term study' which does not represent 'a real life model' ('consultancy work was done, if you like, in a cursory overview manner.'). The areas of biggest concern are the environmental impact assessment, the potential impact Wave Hub would have on shoreline and waves and the well-known situation with the transformers that, in the participants' words, 'simply do not exist'. For example, a few times the participants dismissed Halcrow environmental impact evaluation on the grounds of a timeline and biological cycles. The commercial nature of expertise affected, in the participants' view, the way the consultants approached the tasks delegated to them by SWRDA. 'Pushing the boundaries of technology' in the case with the transformers which they initially specified for Wave Hub could be a good example of satisfying the ambitions of the client (SWRDA) without proper expert evaluation of the feasibility of the proposed technology. This situation is presented as an evidence of their incompetence.

The attitude to large consultancies is not favourable in general: 'there is a huge overdependence on large consultancies who proliferate their own need.. they generate their own demand by overcomplicating all sorts of documentation, and the paperwork sometimes becomes more important than the engineering'.

In contrast to the work done by the consultants the university researchers described their work as academics in a positive way, as 'baseline studies' with the use of more accurate data covering the whole cycle (i.e. prior, during and after Wave Hub installation to assess the impact on 'natural ecosystems', 'pre-installation and post-installation'): '...our data is a much richer source than theirs [Halcrow]; there is a lot more you can do with it and many more detailed questions you can ask and that might be due to the fact that we've come at it from an academic perspective and we've had the luxury of a considerable investment from SWRDA to fund a very broad environmental research programme.'

At first glance, the antagonism expressed in the interviews can be presented as 'discovery' versus problem-solving approach. But it seems to be more than a simple confrontation of two types of expertise: academic and commercial. The main argument put forward in this controversy is the 'independence' of the academics in contrary to the client-oriented expert work done by the commercial consultants (determined by client's needs and expectations). For the members of PRIMaRE it was extremely important to emphasise their status as independent researchers who are in a position 'to act independent honest scientists..<...> to do independent third party expert work'. 'Because we're an *independent academic establishment*, we can be *quite truthful* to the data and understand the impacts – be they good or bad – and provide rather, you-know, 'to the point' assessments *without any external influence of commerce* which is problematic' [emphasis added]. Suspecting an 'underlying agenda' for consultancy work, one of the scientists suggested that in case of commercial expertise data can be sanitised to deliver 'a report to a client' to enable development of projects.

The importance of self-representation as a group of scientists who possess certain qualities (e.g. independence) leads to understanding of expertise as a membership or association and further to the discussion of academic corporate culture.

Seeing themselves on the top of the hierarchy of expertise, the academic scientists do not demonstrate any doubts about how successful their own work is; neither self-criticism nor criticism of their colleagues' work can be found in the interviews[192]. It is not surprising that the vision of PRIMaRE as a 'centre of excellence' is shared and cultivated, being supported with the stories about the acknowledgement of their expertise by device developers and funding bodies. A sort of an 'academic snobbery' as an element of an academic corporate culture became a leitmotif in the interviews with the majority of my participants from the universities. More research is needed to understand to what extent generalisations can be made about the persistence of this tendency across academic communities in general.

7.6. Conclusion

Expert advice has emerged as a crucial theme for analysis of the Wave Hub project. An investigation of the role of experts seems to be important for the analysis of credibility of Wave Hub as a constructed attribute (trustworthiness). The decisions made at different stages of project's development were often presented as proven based on expert knowledge (analogous with Hilgartner (2000) *Science on Stage: expert advice as public drama*). The attempts to present Wave Hub as a credible scientific endeavour required different types and categories of expertise.

[192] It is not excluded that there might be other justifications for refraining from criticising colleagues' work, e.g. self interest in relation to the individuals, good relationships with them, representation of the shared employer/institution etc.

My analysis of interview data has revealed the dynamics and politics involved in the construction of expertise around Wave Hub. This chapter gives an insight into the inner politics of expertise around the Wave Hub project, shows how expertise is built around Wave Hub, what kind of tensions were found there and how the experts position themselves in relation to each other and to the project (self-(re)presentation). I tried to answer the questions posed at the beginning of this chapter concerning the controversies between different groups of experts and issues presented as sensitive, such as data sharing and collaboration with industry.

This chapter not only shows how expertise is performed in case of Wave Hub, but also poses questions about the corporate culture of boundary organisations (as part of the project, with clear dependence on the project development but at the same time positioning themselves as independent and detached), the ambivalence of their position ('independent' scientists – contracts with companies), their attitude to other groups of experts (which also meant constructing their own credibility partly through criticism of other experts). Although the critical claims of the respondents cannot be accepted at 'face value', they revealed the tensions between them and different perspectives adopted.

The question that needs to be answered in the light of the discussion of credibility of Wave Hub is in what ways the politics of expertise affects the credibility of the project. The study revealed certain antagonism and disagreement between different groups of experts. This could in theory undermine the credibility of Wave Hub and eventually its perception as a successful and innovative technological project. However, it seems that the critique of expertise expressed by some of the participants was behind-the-scenes and did not affect the public image of Wave Hub significantly. My analysis of Wave Hub is an illustration of how opening the black box of a technological project leads us to recognise the importance of the politics of expertise for the construction of credibility of the project. The case of Wave Hub speaks forcefully to the idea of co-production (Jasanoff, 2004) of expertise and credibility and the destiny of the project, their mutual dependence and correlation.

Chapter 8. Conclusion

In this dissertation I explored the potential of Science and Technology Studies for studying renewable energy projects. The approaches and concepts in STS, both in discourse analysis and in actor-network theory tradition, turned to be useful for my analysis of the wave energy project. Some of the concepts and approaches were re-examined, in particular, such concepts as possible history, macro-actor and credibility-economy.

Although at the beginning of this research project I did not have a precisely formulated research problem, a critical review of the literature in STS and renewable energy helped to formulate my research questions and find a path into the analysis of a renewable energy project achieving an in-depth understanding of the construction of Wave Hub. The STS literature could also offer the methodological concepts which have influenced my methods of data collection and analysis.

Bringing an STS-formed approach to renewable energy studies, I elaborated an alternative perspective to evaluate the potential of renewable energy projects, which helped to reveal many aspects of the construction of Wave Hub usually missing in the public discourse. Looking at the back-stage of the project helped to get a glimpse into controversies, contradictions and antagonisms which appeared central to the construction of the project's credibility as an emerging property of a macro-actor and as a multidimensional construct. This study also provided an insight into the politics of expertise surrounding a big technological project and allows us to understand how it was constructed as a credible expert endeavour. It also dissected the notion of what constituted wave energy as part of policy discourse. An ANT-informed approach for analysis of Wave Hub allowed me to suggest a new way of thinking about renewable energy policy developing an idea of policy as an actant and providing insights into the complexities of policy as an actor-network. I see this as my original contribution to macro-actor studies in STS.

The originality of this thesis is in using a narrative historical approach to explore a renewable energy project in order to locate its position in relation to renewable energy policy (policy network) and dominant narratives around renewable energy, particularly in the UK, where the dominant market-led approach does not necessarily encourage less proven technologies and more decentralised forms of energy supply. Thus, my approach seeks to widen conventional analysis of 'policy' beyond a contextual understanding where policy forms the background to decision making, in order to see it as an evolving actor-network where 'content' is constructed and interpreted around a particular initiative – the Wave Hub project.

This chapter draws further as to what has been gained from this research project and what could be the implications of this study for STS and renewable energy research, and in particular, what my analysis of policy, expectations and expertise in wave energy could suggest for understanding of socio-technical change as part of energy transition to sustainable energy futures.

Macro-actor and boundary work

In order to highlight the originality, first I would like to emphasise that this dissertation has made a contribution to macro-actor studies. In my thesis I draw on a concept of macro-actor to investigate a technological project, Wave Hub, as a large complex socio-technical system (an evolving heterogeneous system or an actor-network).

The macro-actor studies discussed in the literature review illustrate flexibility and versatility of the concept, which has proved to be useful for analysis of different cases and applicable for different sites addressing various research questions, from a single technology, e.g. an engine, to an organisational routine or markets (e.g. Lindahl, 2005; Feldman and Pentland, 2005; Callon, 1999). In my dissertation I extended the concept of macro-actor to studies of renewable energy and tried to demonstrate the utility of this approach for analysis of emerging industries, such as wave energy industry.

It is suggested that the construction of macro-actors and the processes that stand behind are 'poorly understood' due to solidity and consistency in descriptions of objects or phenomenon (e.g. technologies) which often presented as being 'indivisible and solid' with the traces of construction are wiped away (Czarniawska and Hernes, 2005, p.7). Therefore, macro-actor is a worth concept to pursue as it allows us to understand dimensions which might not be apparent when studying a phenomenon using other analytical approaches. In my thesis I wanted to challenge common perception of the renewable energy project (i.e. the received view of Wave Hub as a 'simply' socket with a cable placed in the sea) and instead make visible heterogeneous networks that constitute Wave Hub. Moreover, I tried to appreciate Wave Hub as a macro-actor 'in the making' and showed how it comes into existence paying attention to all possible dimensions of a macro-actor and its dynamics. This approach also helped to trace and tease out the fragility of the macro-actor construct. The thesis provides an insight into complexity of actor-networks, and further arguments can be developed based on my case study that would help to understand how fragility of Wave Hub as a macro-actor is overcome temporarily, not least through the dynamics of (unmet) expectations. As such new understandings of how collectives emerge, organise and possibly get stabilised can be produced.

In order to answer the research questions posed in the beginning of the study, I started my empirical analysis with re-constructing the possible history of the Wave Hub project trying to trace the evolution of a technological project as a macro-actor, with a focus on various actors enrolled and aligned at the different stages of project's development. I examined the process of creation of alliances that formed the basis of this construction with the main focus on the controversies and negotiation processes throughout the project evolution. Special attention was paid to the analysis of contingencies that conditioned the perception of the project's success or failure. Construction of a macro-actor goes beyond the task to produce a single (or even multiple) description of the project. Although this story can be seen as an exercise in constructing a historical narrative and creating an analytical account of the evolution of a macro-actor, the purpose of this narrative was not only to give a detailed description of the project, but rather to tease out key theoretical themes pertinent to the construction of a technological project, e.g. construction of the credibility and expertise.

Trying to understand what Wave Hub as an evolving actor-network is, I explored the participants' visions of a macro-actor, which led to the idea of its relational character. The construction of the boundaries of an actor-network and within it was represented by complex processes of negotiations and deliberations between actors themselves, and between actors and the analyst. As such, the boundaries of the actor-network and the contested nature of those boundaries were the subject of the analysis. The intention was also to study the boundary work performed in the case of Wave Hub and to explore the idea of changing boundaries between natural and social, technical and non-technical, between what can be controlled and what cannot. From ANT perspective, it has been suggested that a technology might have different boundary configuration depending on the meaning attributed to it (Laet and Mol, 2000), and this has a direct bearing for the analysis of the case of Wave Hub. The boundaries were defined by the participants themselves through the meanings attributed to the project and affiliated entities (e.g. PRIMaRE), they were also shaped partly through media resources (including online resources) and policy discourse.

The question of boundaries also involved deliberations about boundaries between social and technical in a macro-actor. One of the situations where such boundary work was very prominent was development of a design of a technological artefact (the technical decisions were largely informed by social constituencies negotiated in the course of the development of technical solutions).

Following the actors taken as a methodological strategy helped to reconsider the approach to analysis of a technological project in terms of multiplicity of meanings of technology, its contested and relational character. In this thesis I tried to develop conceptual means to understand the production of boundaries of a macro-actor and the process of boundary work that represented an ongoing process based on negotiations and re-negotiations between different actors.

Analysis and description of macro-actor seems to be a messy textual practice because of a number of overlapping concepts, as well as a desire of the analyst to cover as many aspects of a macro-actor as possible. In order to explore Wave Hub as a complex multidimensional construct and enrich my analysis of the macro-actor I brought an STS version of discourse analysis to macro-actors studies and suggested a composite framework as a methodological basis. Constructing a macro-actor goes beyond the task to produce a single (or even multiple) description of the case – in my case study I traced several narratives describing a macro-actor (e.g. a historical narrative, 'policy as actant' narrative, a credibility narrative, an experts' narrative). I suggested that the complex analysis of a macro-actor can raise visions of other possible lines of inquiry and helps to elaborate further research questions, e.g.

construction of credibility of Wave Hub as a macro-actor. Going beyond ‘traditional’ ANT analysis might bring new insights which nevertheless can co-exist in particular case study. As such, it was seen as analytically fruitful to combine ANT and discourse analysis which helped to overcome the limitations of ANT and enrich the understanding of construction of Wave Hub in its various manifestations – as a macro-actor and as a product of relevant discourse (a discursive construct). While the ANT approach helps to build a ‘thick description’ of a technological project (a macro-actor), the analysis of accounts, their variability and functional dimensions allowed me to explore the construction of credibility of a technological project investigating a macro-actor in its various manifestations.

Policy as actant: from the idea of scale to the idea of agency

An ANT-informed approach for analysis of Wave Hub also allowed me to suggest a new way of thinking about renewable energy policy developing an idea of policy as an actant contributing to a greater understanding of the complexity and dynamics of policy framework around renewable energy in the UK.

The traditional view of policy as a macro context dominates in the literature on renewable energy policy and innovation. In the literature review I provided a comprehensive analysis and elaborated focus to critically evaluate the externalist view of policy as a macro context in the so-called positivistic literature on renewable energy and innovation.

The main purpose of discussing the story of Wave Hub as a macro-actor and bringing in an ANT perspective was to investigate an analytical approach to policy as an actant, not merely a context. For this purpose I discussed the wave energy industry and renewable energy policy in the UK and paid special attention to analysis of policy discourse in the field of renewable energy.

Policy also emerged as a significant part of participants’ discourse describing a macro-actor. Based on the analysis of my empirical data, and first of all, the participants’ accounts on policy issues that arose in the case of Wave Hub, I developed my approach to understanding renewable energy policy for the purpose of this study as a relatively stabilised and powerful actor-network comprised of heterogeneous elements. This approach helped to conceptualise the role of policy in the construction of a macro-actor and the role of promissory discourse in building credibility of the Wave Hub project. Moreover, this approach provides a new perspective on performative role of networks and mutual constitutive effect achieved in such configurations. From this perspective, it is possible to talk about the promissory role of a policy network in construction of credible claims around Wave Hub, thus linking my analysis to the body of research in the sociology of expectations in STS.

The theme of policy was the most prominent in my thesis, and I touched on it in different chapters of the dissertation studying not only participants' accounts but also policy discourse around renewable energy in general and wave energy in particular, critically reviewing the existing literature in the field, analysing representation of wave energy in policy documents.

Policy discourse through which policy gains its legitimacy was a subject of scrutiny in this thesis. I studied policy documents that created a framework for renewable energy development and analysed relevant policy discourse. Policy documents considered in this study were understood as socio-historical artefacts which depicted particular policy understanding of wave energy in the socio-historical context in the UK. They played a crucial role in constitution of renewable energy, including wave energy, as a policy category. My analysis suggests that policy vision of wave energy relies on science and technological development to achieve policy goals. Such technocratic visions of wave energy and renewable energy futures are largely informed by commodification and technologising of wave, which would allegedly lead to 'unlocking the potential' of wave energy. It became apparent that such documents are largely informed by pre-constructivist understanding of technology and heavily rely on promissory discourse informed by technocratic vision of the object of regulation (i.e. renewable energy or wave energy). In line with a central premise of STS to look at the construction of content of scientific research and technological development, technologising wave appears to be a nexus around which policy, science and industrial aspirations converge.

Credibility as a multidimensional construct

Developing the argument about the role and effect of policy network, and especially policy discourse, in construction of Wave Hub as a macro-actor, I came up with an idea about politicisation of Wave Hub. This has a direct bearing to the question of the credibility-economy of the project, as the political dimensions of a credibility construct appeared to be extremely important. Existing literature is lacking critical empirical engagement with the practices of construction of credibility of renewable energy projects, and in this thesis I tried to develop conceptual means to understand the construction of the credibility of Wave Hub as a renewable energy project which aims to facilitate the deployment and further development of marine energy technologies in the UK.

My analysis is based on the thesis about credibility as a constructed attribute of a technology which was built upon expert knowledge (presented as such), combined with political support and ideology of clean energy and sustainability (i.e. politicisation of Wave Hub).

The analysis of the construction of the credibility of a macro-actor and legitimate decision-making at different stages of the project development brought into focus the question of the symbolic capital of the project, the assessment of its success and/or failures, as well as the issues regarding expertise and expert knowledge formed around the project. It was important to understand what stands behind the notion ‘Wave Hub’, to assess to what extent the distinctive features of the project were the means for constructing credible claims, and how reliable and persuasive the rhetoric used to communicate the case was (e.g. justifications).

I suggest that the official recognition of the project’s success, despite of a number of failures and delays, is the evidence of the strength of the credibility construct around Wave Hub. It was apparent that the idea of sustainable energy, cultivated in society for the last decade, helped to build a solid foundation for any renewable energy development. The generally favourable public perception and preparedness of the society to accept such developments construed a positive image projected on Wave Hub, which was conceived under the so-called ‘umbrella’ of the sustainability concept. The perception of renewable energy in society is generally positive, and creates a ‘congenial credibility-environment’ (Shapin, 1995, p.264) for Wave Hub and for the claims about the benefits for society in general, and for local communities and renewable energy industry in particular. Although a number of controversies arose, being in the domain of sustainable energy was the obvious advantage of Wave Hub for its perception by the public and for solving many of these controversies or at least for achieving presentation of disputes as settled.

Negotiated economic and social value of the Wave Hub project made this development symbolic of the region and of the wave energy industry in the UK. It can be suggested that through its symbolism it also added legitimacy and contributed to the construction of expertise and expert status of many of those who were involved in its development (e.g. PRIMaRE or the companies who executed the project). The discussion about the symbolic meanings of Wave Hub and its symbolic capital also contributed to creating a picture of a macro-actor in its various manifestations.

The message about complementarity of Wave Hub with existing configuration of marine energy testing facilities in the UK also strengthened the argument for the credibility of both, a new wave energy project and an existing network.

The concept of credibility builds the groundwork for approaching a discussion of the success and/or failure of the project. The evaluation of Wave Hub by different groups of participants can help to establish or deconstruct credibility of the claims about the project’s legitimacy and success. If successful, it forms a favourable attitude towards Wave Hub and creates certainty around the project in the sense that it is perceived as a doable endeavour.

The key issues that came up in the discourse of Wave Hub were the ideas of success and failures which often were constructed through the accounts of contingencies as conditions for success and/or failure of a technology.

I suggest that the success of Wave Hub appeared to be a matter of perspective (a relational matter). My analysis shows that the criteria for assessing the success of Wave Hub and its performativity could not be clearly defined and had different interpretations. Answering the question of what it means for Wave Hub to be a successful project one can refer to its dependence on other actors – first of all, device developers and their WECs that can put life into this facility. Employing a concept of a macro-actor as an evolving actor-network brings a new perspective as the project would be seen not simply as an artefact, i.e. a cable and a hub on the seabed connected to the electrical grid but rather as a component in a complex configuration of networks.

It also implies that the simplistic approach to classifying events as either success or failure cannot satisfy the analysis of a macro-actor. For example, the questions if the failure of the wave energy industry to utilise the facility at the time of its construction automatically undermine its credibility cannot be answered using such simplistic approach.

The credibility-economy of a technological project is an evolving category. As the project's cycle has not been fulfilled, and new actors are still to come to the scene (i.e. device-developers), it could be suggested that the question of credibility would be modified and, for example, complemented with a question of reliability of the facility, which will be viewed in a new light as with many other technical systems in the process of usage.

It is apparent that the political and economic interests were mobilised around the credibility of the project. It became a highly politicised affair, but the legitimacy and credibility of Wave Hub were established not only on political but also on scientific grounds. In modern societies science is recognised as a legitimate trustworthy source of knowledge, so the involvement of experts (including academic experts) was a crucial factor for constructing the credibility of Wave Hub. Moreover, this case allowed talking about the co-construction of credibility and expertise, which is one of the key arguments in this thesis.

The theme of expertise and expert knowledge is inevitable when the discussion is formed around a technological project, new technologies, and innovation, which require specific knowledge of the subject and are related to the participants' professional activities. The ambiguities encountered in the case study provoked disagreement, controversial opinions and speculations. Therefore, the expertise and expert status of the participants became important in the discourse about the controversial aspects of Wave Hub.

The attempts to present Wave Hub as a credible scientific endeavour required different types and categories of expertise. Thus, the discussion about the politics of expertise around Wave Hub included the question of categorisation of expertise with particular focus on the politics of commercial expertise and the production of academic expertise around Wave Hub, as well as the hierarchy and the antagonism that was revealed between different types of expertise. This study also provided an insight into the culture of boundary organisations and the ambivalence of their positions.

Summing up the concluding points, Wave Hub as a macro-actor emerged through resolving controversies with technical and managerial decision making; policy demands and accountability; the politics of expertise; as well as public acceptance of such projects. The aim of this study was to explore alternatives to understanding wave energy projects, and ‘wave’ in particular, in terms of technoscience, rather than discussing advantages and disadvantages of renewable energy. Even on the contrary, I tried to discuss the emergence of renewable energy as ‘advantageous’ as compared to other sources of energy through configuration of networks and construction of the credibility of the wave energy project.

As a result of my analysis some theoretical points can be reconsidered. In this study I attempted to introduce a new different methodological approach to exploring the barriers and challenges which lie around the role of renewable energy in the shift to a low carbon economy. A new perspective on policy as a heterogeneous network developed in this thesis is an idea that probably can help to change the framing for policy advice and analysis. I also suggested a move from discussion of politics of artefacts to politicisation of a technological object that I found in my case study as a deliberate process mainly performed through public discourse. Analysis of policy discourse associated with renewable energy, and in particular, wave energy, also helped to understand how renewable energy as a policy category is constituted and stabilised.

The core of ANT is an analytical approach that helps to understand how new objects (e.g. a technology) or phenomena emerge and stabilise in a process of ordering social worlds. Technologies like Wave Hub is an example of such objects, and my research confirmed that the Wave Hub project was an interesting case for analysis from this perspective. My analysis of Wave Hub as a macro-actor is an example of how such important aspects as credibility, politics of expertise and materiality are brought into discussion. It can be suggested that the methodological and analytical approaches formulated in this study would be useful for exploring other technological developments and emerging industries (renewable energy sites and initiatives), and perhaps would enrich the spectrum of analytical perspectives contributing to development of new lines of inquiry in energy studies and STS.

Reflecting on the possible audience of this PhD thesis, I would suggest that the study also has a potential contribution to the growing body of literature on energy transitions. Energy transitions has been conceptualised as a path creation for emerging industries with increasing recognition of the deficiency of linear approach replaced by attention to contingencies. It is recognised that ‘transitions are far from unidimensional or predictable: they are multiple systemic pathways that might evolve and that can only be assessed as they emerge’ (Verbong and Loorbach, 2012, p.11).

In order to make visible important aspects of energy transformation that might go unrecognised and unacknowledged, it is suggested that energy debates need to be informed by robust empirical and theoretical inquires into current and future energy changes (Miller et al., 2013). My study offers such empirical input to the current debate on energy transition and contributes to the understanding of construction of heterogeneous energy futures. It provides an insight into renewable energy development and the process of path creation for emerging renewable energy sector, in particular wave energy industry, as part of a transition to sustainable energy futures. It reveals some imminent problems and contradictions of this process, helping to understand how new structures emerge, and how the socio-technical changes happen. New conceptualisation of policy which accompanies these transformations (policy as actor-network, policy as actant) suggested in the thesis might be used to develop a better understanding of its complex heterogeneous character, its performativity and evolution, and possibly to improve the mechanisms to address the existing and future challenges for renewable energy policy in the UK. Drawing on STS sensibility, the study adds to systemic thinking about energy transitions in tradition of technology studies integrated analysis.

The actor-network approach and the concept of macro-actor, suggested in this thesis for analysis of technological innovation in the energy sector, can challenge the more traditional approaches to energy transitions as it helps to understand and address resistance to innovation and social change which is often the case with new initiatives and technologies. This approach can possibly answer the questions about how to integrate innovation with existing configurations and social structures of modern societies, how to use existing structures in support of innovation and change. ANT analysis, and in particular a macro-actor approach might be useful as it is focused on interactions of wide range of elements, human and nonhuman, not only a few variables, and can offer a more inclusive description of networks and processes helping to understand the dynamics of change.

Similar efforts to reconsider approaches to the construction of technological futures (in both practice and theorising) can be found in the domain of technology assessment. Most pertinent is a study by Grunwald (2011) which asks questions about quality of energy futures based on understanding that those futures are heterogeneous and contested. My case study has highlighted aspects of the construction of Wave Hub that speak to what is important to both recognising heterogeneity and contingency of energy futures. One source of contingency is expectations about the future of renewable energy projects which can be approached from the perspective of sociology of expectations in STS.

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