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The Technological Field

*Technological Innovation in the UK
Marine Energy Technology Sector*

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PhD in Sociology

The University of Edinburgh

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Declaration Page

This is to certify that the work contained within has been composed by me and is entirely my own work. No part of this thesis has been submitted for any other degree or professional qualification.

To Elli and My Family

Abstract

The aim of this thesis is to develop an innovative theoretical understanding of technological innovation as a social phenomenon and to demonstrate the results of its application to the sector of UK's marine energy technology. Via a creative analysis and critique of various theoretical approaches to technology, I identify several key elements of a theory capable of understanding technological change, which I then develop based on the critical juxtaposition of the approaches of Pierre Bourdieu and Cornelius Castoriadis. Technological innovation is understood as the ultimate outcome of the relations of cooperation and competition formed by radically creative agents, capable of ex-nihilo creation, who participate in private and public institutions of a quasi-regulated technological field. After arguing in favour of applying a primarily subjectivist epistemology with objectivist elements, I present a research methodology based on semi-structured interviews. The results of the data analysis highlight several key features of technological change as it takes place within the technological field of UK's marine energy technology. Firstly, I present the ways the technological field influences the agents therein and helps them develop their craft. Secondly, I explore how the agents of the field use their craft as they

create ex-nihilo. Thirdly I show the interactions between the technological field and other social institutions/spaces such as the economic sector and the general public. Subsequently, I analyse the internal organization of the technological field and its impact upon the trajectories that technological innovation follows therein. Finally, I make the first tentative steps towards developing policy advice for the sector. I conclude that, as long as policy makers manage to develop a precise understanding of the technological field of marine energy technology, then they actually can design policy capable of positioning the technological innovations therein within a preferred path.

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Chapter 1: Introduction

Technology is the frontier between the social and the natural world. Technological entities, i.e. artefacts and processes are created by humans but at the same time their characteristics depend significantly on their material properties. The main reason why social science has developed many diverse and distinct interpretations of technology is exactly the hybrid character of this phenomenon. Nevertheless, my view is that to develop an understanding of technology, it is first necessary to develop an understanding of how it is created. Hence, it is crucial to achieve an understanding of *technological innovation*. This thesis is an effort to develop an understanding of technological innovation as a social phenomenon. To achieve this aim, I explore the social aspects of the development of marine energy technology in the UK. I develop a narrative of the interactions between specific technological artefacts (in that case marine energy production devices) and Scottish institutions and society, as the former changed over time.

Even so, before analysing the sector of marine energy technology, I had to find out what would be the correct way of investigating technological innovation as a social phenomenon. Could the answer to this question best be answered by a technologist? If so, then in the case of marine energy technology, I would have to study

engineering and eventually work in the sector and construct marine energy technology. However, by following this approach I would have developed an understanding of technological innovation as a technical and not as a social phenomenon. Understanding technological innovation as a social phenomenon means that I will have to develop a narrative of how society influences technology (and vice versa) beyond the level of the construction of technological entities. In which case, creating an account of the actions of the engineers, their thoughts and motivations for their work, is also a part of the problem of developing an understanding of technological innovation. And this is not possible had I become an engineer myself.

To understand the behaviour of engineers, I would have to first take technology's hybrid character under consideration. After all, it is not surprising that the social sciences decided to try to develop an explicit understanding of technology relatively late in their history. Even though all grand social theories of the 19th century such as for example rational choice theory (Varian, 1992) and Weberianism (Weber, 1905) also discuss the issue of the impact of technology on society and vice versa, sociological approaches which are explicitly designed to understand the phenomenon of technology belong to the latter half of the 20th century. Even in the case of philosophy, only after the development of Husserl's (1936) and Heidegger's (1927) phenomenological approaches, did the

more systematic reflection regarding technology escape the margins of the discipline.

This is quite surprising. No matter how hybrid technology might be, it still remains one of the most important components of the social world. It would not be far-fetched to say that one of the defining characteristics of humans is that they use and create technology. Humans through the use of technology firstly transform the natural environment in which they live and then construct an artificial environment which is not only necessary for their survival, but also full of diverse and distinct entities and concepts the exact form of which can only be attributed to human inventiveness and not to any natural or historical 'law'. Human socialisation takes place within an already instituted world characterised by specific types of material culture. It is this material culture that humans use without even noticing when they perform even the most mundane and trivial actions of their everyday lives. The significance of technology is so great that it would perhaps be better, following Emery and Trist (1960), to replace the term social reality with socio-technical reality. Given this condition, understanding the phenomenon of technology should be one of the primary targets of the social sciences. The first motivation behind this research was therefore to develop an understanding of the creation of technological entities which can be translated as an amalgamation of both the human capability to induce

change and its roots which can be found in its pre-existing natural and technical environment. Or, to rephrase, I was curious about the ways in which humans interacted, transformed and organised their world to satisfy their needs. The need to address the issue of this hybridity of technological entities is also the first step towards the articulation of an approach capable of providing a social scientific understanding of technology.

However, the need to discuss the ways interacting humans transform their world and construct an artificial environment means that it is impossible to understand technology as a stable entity. This is one of the key difficulties in a social scientific investigation of technology. Technology is a carrier of both stability and change in human lives. The specific types of technology available to humans are indispensable components of their stable routinised behaviour (see for example Latour, 1992). However, this is only the first side of the impact of technology. The other side is the change that is provoked each time new technological artefacts or processes are introduced in socio-technical reality (see for example Soete, 1987). Sometimes that change and knowledge of it might influence only a small number of experts or technologists who actually handle specific technological entities. Or, it could influence a large number of people to an extent that it might

become an object of fascination and admiration such as in cases of technological hype (see for example Campbell and La Pastina, 2010).

Therefore, my research project is constructed upon the foundations of a theoretical framework capable of providing insight about these two ways of experiencing technology within socio-technical reality. And the need to understand change means that a prerequisite to providing insight, regarding the emerging and ever-present diversity of technological artefacts and processes, is the investigation of the efforts of human agents to achieve technological innovation. Hence, the second motivation behind this research was to examine the phenomenon of technology as a dynamic phenomenon, i.e. a phenomenon of potential change intentional or unintentional in order to avoid the trap of envisaging technology as simply the stable background of the lives of humans. On the contrary, it is necessary to understand it for what it actually is: a constellation of entities which induce both stability and change in socio-technical reality.

This is even more important to modern societies (even though technological change is a permanent feature of human history); a defining feature of which is exactly the speed of technological development, among other changes (Misa et al., 2003). In contemporary modern societies technology is so prevalent that scientists have started warning about the potential perils of the development of artificial

intelligence (Hawking, 2014). It is obvious that a technological change can have better (e.g. an improved standard of living) or worse (e.g. increases in pollution) consequences and, hence, understanding the multiple facets of this phenomenon should concern not only scientists but everyone.

This leads to the third motivation behind this research. As the title indicates, this research is a case study of a specific technological sector: marine energy. Marine energy is energy generated from the motion of waves and tides. It is a technological sector which shares many common characteristics with the already established sector of wind energy. And, just as all sectors of renewable energy, it is of paramount importance in order to achieve a future in which humans will stop relying on only a small number of sources of energy, such as the highly polluting fossil fuels. This importance is exacerbated even more in the case of this research which will focus on the development of the marine energy technology sector in the UK and, more particularly, Scotland. The Scottish economy, just like the rest of the UK and beyond, has suffered the impact of the 2008 global economic crisis and the development of its renewable energy sector could reduce its dependence on the imports of fossil fuels and at the same time function as a positive shock to its economy. To Scotland in particular, marine energy is of even greater importance for two reasons. Firstly, Scotland possesses the

largest marine energy resources in Europe, i.e. 10% of Europe's wave energy potential and 25% of its tidal energy potential (Scottish Government, 2014a). That means that the development of these sources of energy could boost its economy. The abundance of marine energy resources has contributed to Scotland's decision to set a target of producing 100% of Scotland's electricity demand by renewable energy sources by 2020 (Scottish Government, 2014a). Secondly, Scotland is a semi-autonomous country within the UK. It is argued that the development of its marine resources could help Scotland reduce its dependence on the rest of the UK. At the time of writing, Scotland had just said 'No' to its independence in an independence referendum and was expecting to achieve a higher degree of devolution in the UK. One of the decisive factors for this referendum was whether or not the Scottish economy would be strong enough to survive without maintaining its ties with the rest of the UK (Scottish Independence Information, 2014). Independent or autonomous, the capability to develop and exploit its natural resources would be one of the determinant factors of the survivability of the Scottish economy. The simultaneous occurrence of an abundance of natural resources (an enabling factor for innovators), and of a specific significant historical conundrum (environmental decay, potential independence and economic crisis) which rendered the development of this type of renewable energy

necessary to the Scottish economy and people, made the sector of Scottish marine energy technology an ideal location to study technological innovation. Hence, taking into account the historical circumstances in which the development of Scotland's marine energy technology unfolds is the third step towards providing a social scientific understanding of technology.

So far, I have presented the topic of this research and described the three steps towards the articulation of a social understanding of technology, i.e. the need to understand the hybridity of technological artefacts and processes, the need to address technology as a carrier of both stability and change, and the need to develop a historical account of technological change. It is important to remember that these three factors are not simply steps towards the construction of a new approach, but also necessary components of an understanding of technological innovation and hence, technology. A sociological understanding of technology necessarily has to accept that there are interactions between society and technology and that the latter partakes in the formation of history through the effects it has upon human societies. Had it been otherwise, technology should be described as something that has random effects on the world.

However, taking into account these three steps does not suffice. A prerequisite for the successful investigation of technological

innovation is the formulation of specific research questions. These questions set targets for my research and distinguish what is important to research this phenomenon. What follows is a description of these research questions.

- Research Question 1: What *is* technological innovation?

This question has to do with the *Being* of technological innovation as a social phenomenon. Hence, it is an *ontological* question.

- Research Question 2: How could researchers obtain

knowledge about technological innovation? The second question is the *epistemological-methodological* question. After the development of the ontology of technological innovation, it is necessary to produce *epistemological* principles which do not contradict the ontology of this phenomenon as well as a *methodology* capable of providing valuable data for the understanding of specific technological innovations.

- Research Question 3: How does the behaviour of

technologists affect technological innovation and its qualitative characteristics? This is an *anthropological* question. It is an attempt to find out the ways through which the conditions of a specific technological sector affect the technologists therein and how these technologists in their own turn affect the qualitative characteristics of technological innovations. The term anthropological in this case does not imply that this question forms part of the sciences of social or natural

anthropology. I use this term because it denotes the need to describe how *humans* interact with technology. After all, it is only through the understanding of the creators of technological innovations that it is possible to develop an account for the latter.

- Research Question 4: How do the interactions among various institutions affect the dynamics of technological change? Since technologists work in specific institutions, the purpose of this question is to investigate the interactions of these institutions and their impact on technological innovations. It is the *institutional* question of this research project. The thorough description of the specific technological sector it aims to achieve, combined with the results of the analysis of question three will help me uncover the dynamics of technological change in the sector of marine energy technology.

- Research Question 5: Is it possible to develop policy advice via this type of research? Any type of research has to be in a sense beneficial to a society, even though the definitions of such terms are always controversial. Hence, this is the *policy* question.

There are two reasons why I chose to start my analysis at the ontological and not the epistemological level, i.e. from question one and not from question two. The first reason, as already discussed briefly is that the only way to understand technological change is to develop a theory capable of describing all the potential interactions between

technological artefacts and processes and humans, and especially how and when the latter are capable of changing technology and producing technological innovations. However, if, at the same time, technology is an essential component of any human society, and one of the most important determinant factors of stability and change in human lives, then understanding it also means understanding specific aspects of the interaction between the human agent and socio-technical reality as a whole. A prerequisite for such an understanding, however, is specifically the construction of an ontology of the human agent and of its interactions with technological entities.

The second reason why I decided to start from an ontology of the relations between human agents and technology is because any knowledge that I generate regarding the issue of technological innovation belongs to the same socio-technical reality as the innovation itself. Since knowledge is only a part of socio-technical reality, understanding how it can be produced presupposes an understanding of socio-technical reality itself. After all, even the simplest epistemological principles 'hide' specific assumptions about the Being of the world humans live in. To give some examples, the assumption of social constructivists that knowledge is finite, i.e. that it is the result of the negotiation among human agents, is based on the ontological hypothesis that humans have the capacity to develop different categories in their

thought. Hence, they are able to engage in conversation and negotiation in order to develop specific types of knowledge (Barnes et al., 1996).

If it is necessary to start this research by articulating the ontology of technological innovation, then I have to describe the characteristics of this ontology. This is a difficult task because there are many different socio-theoretical approaches to technology, each with its distinct ontology. Chapter 2 aims to start providing an answer to the ontological question. The starting point of this enquiry is an understanding of the concept of technological innovation which consists of three components. Firstly, technological innovation is a 'craft', i.e. it is the human capability to construct and use many different diverse and distinct entities. Secondly, technological change occurs according to a reasoning which is related to the ways societies change. Thirdly, technological innovation represents a rupture with previously existing socio-technical reality. After the presentation of these key ingredients of technological innovation, I analyse various contemporary philosophical and social scientific approaches to technology. Each theory was evaluated according to how successfully it could understand each of the three components of technological innovation. Some of these theories find it more difficult to understand the 'craft' aspect of technological innovation whereas others are unable to find the reasoning according to which specific innovations occur. However, I will argue, following

Castoriadis (1975), that the majority of contemporary approaches to technology, just like the majority of contemporary social scientific and philosophical theoretical frameworks, followed an ensemblist-identitary (ensidic) reasoning, i.e. they presupposed a principle according to which change in the socio-technical realm unfolded. To be more precise, they claimed that technological innovation was a phenomenon the Being of which was determined. However, in the case of technological change this is problematic since it is a phenomenon which displays hybridity and constant transformation and cannot be encapsulated by a single ontological principle no matter how elaborate that might be. In addition, again following Castoriadis (1975), if the Being of technological change is ensidic, then there is no real creation. Everything is a derivation of some aspects of pre-existing socio-technical reality. Hence, it is difficult to understand breaks with major socio-technical regimes which usually include (and in some cases might even be induced by) specific technological innovations. These weaknesses justify the construction of a new social scientific approach to technological change.

Chapter 3 is the place where I move beyond the analysis of other approaches, develop a complete answer to the ontological question and construct a new ontology of technological change. The first characteristic of this ontology is its adherence to the relational character of technological innovation. What that means is that it is impossible to

understand a technological innovation as an isolated event. Instead, it is necessary to examine the relations among agents and institutions that contributed to its emergence and the social background behind these relations that generated them. This relational approach offers the opportunity to compare and contrast the features of technological innovations in highly distinct technological sectors. However, a relational approach is an abstract term, since many sociological approaches identify themselves as relational (e.g. complexity theory is one [Cilliers, 2005]). Hence, to be more precise, my approach is relational in the sense that, following Bourdieu (1972), it claims that technological innovations occur within an instituted social space, the technological field. Within this field, agents and bureaucratic institutions compete for various types of capital, the main types of which are financial capital and two types of cultural capital, technological and bureaucratic. The Bourdieuan field is a concept which is able to incorporate the majority of the strengths of the theories that I will examine in Chapter 2.

The problem however is that the field is a part of an approach which does not manage to escape the ensemblist-identitary character of modern ontologies. The reason is that, if the field is to be of any importance in the determination of the behaviour of the agents therein, it requires an internalisation ‘mechanism’ via which the structure of the

field determines the thoughts and practices of its agents. Bourdieu (1980) proposed that this 'mechanism' was the habitus, a structured structure that functioned as a structuring structure. The problem is that, according to the habitus, the internalisation takes place unreflexively. Hence, it is impossible in the Bourdieuan analysis to understand the internalisation of structures which emerged at the moment of action (Mouzelis, 2008).

To avoid the ensemblist-identitary character of Bourdieuan analysis, I decided to develop a new approach to internalisation. This approach is based on the concept of *radical creativity*. Radical creativity includes two components: the capability to create ex-nihilo and the perspective. The former is the constant activity of the psyche for creation. The possibility of ex-nihilo creation is what makes Castoriadis's (1975) theorisation capable of escaping the trap of adhering to a modernist ensemblist-identitary ontology. However, this capability by itself is unable to explain how the ex-nihilo creations combine with elements of pre-existing socio-technical reality in order to produce meaningful innovative thinking which could lead to successful innovations. Hence, what Castoriadis calls radical imagination has to be complemented by the perspective. The perspective is the created assemblage of recreations of elements present within pre-existing socio-technical reality which the agents learn through their personal experiences. Human agents build their perspective by performing

innovations, through their radical imagination, which allow them to know how to interact with socio-technical reality. It is important to point out that these innovations can either be personal, i.e. the agents simply learn to perform in ways which have already happened before, or societal, i.e. the agents perform in ways which have never been seen in the history of socio-technical reality. Therefore, the perspective and its interaction with the radical imagination is capable of replacing the habitus and avoids the deficiencies of ensemblist-identitary ontologies, since it can understand innovative reflexing thinking. Hence, the technological field becomes an instituted social space where radically creative agents perform personal and societal innovations within institutions which cooperate and compete in order to accumulate specific types of instituted capital.

Based on the ontology developed in Chapter 3, Chapter 4 aims to provide an answer to the epistemological-methodological question. I favour a primarily subjectivist epistemological stance, because the only way to understand the technological field is to uncover the characteristics of the perspectives of its agents' radical creativity, and these are strictly personal creations. However, this subjectivist epistemology has to be complemented with specific objectivist elements for two reasons. Firstly, the existence of the technological field means that the agents therein share some experiences and hence, some elements in their perspectives.

Secondly, the fact that this research is about technological innovation means that the agents of the field share some elements in their radical creativity because they had to experience specific aspects of the nature of technological artefacts which are beyond human influence. And certainly this epistemology leads to specific methodological propositions.

Hence, Chapter 4 continues with the presentation of the methodology of this research. This research was based on semi-structured interviews, since one of the best ways to approach an agent's perspective is to give them the opportunity to reveal some of its elements. Twenty-five people who are active in the technological field of marine energy technology agreed to contribute to this research. The questions in these interviews were constructed upon the findings of background work based on online and documentary research. The purpose of the documentary research was to reveal the most basic characteristics of the technological field, i.e. to translate into data the objectivist aspects of the epistemology of this research.

Chapter 5 is dedicated to the presentation of the findings of the background research, i.e. a rudimentary description of marine energy technology and of the institutions that deal with it within the field. The field of marine energy technology is divided into two subfields, those of wave and tidal energy technology. The life of innovative wave or tidal devices starts with their invention by engineers who work in developer

firms or university departments (or in collaborations of these two types of institutions). Funding comes largely from the private sector, and in particular consortia of investors, even though the public sector maintains a really important supporting role in the industry. The main priority of the public sector is to function as the regulating agency of the field. Finally, there are several institutions of the private sector that perform peripheral and supporting functions in the field such as for example consultancy firms.

Chapters 6 to 10 provide the answers to the empirical questions of this research, i.e. research questions three and four. To be more precise, Chapters 6 and 7 focus mostly on the description of the radical creativity of the agents of the field, their perspective the former and their capability to create ex-nihilo the later. Hence, they address question three, i.e. the anthropological question of this thesis. In Chapter 6 I show that that the perspective of the agents is shaped mostly by their early age experiences, the values to which they adhere, and their personal interests. The latter two categories are determined mostly by their position inside the technological field. Chapter 7 proceeds from the analysis of the perspective of the agents to the investigation of their capability to create ex-nihilo and how that relates to their perspective. There are similarities in the way the majority of the interviewees describe how they arrive at innovative ideas. What is of even greater importance, however, is that

the information internalised by the interviewees in their perspective, is a prerequisite for innovative reflexive thinking. Hence, habitual and reflexive thinking should not be described as two entirely different ways of experiencing socio-technical reality. The former depends on the function of the latter.

Chapters 8, 9 and 10 leave the analysis of radical creativity aside and attempt to describe the technological field per se. Hence, they answer question four, i.e. the institutional question. In most cases, the analysis of the data confirms the hypotheses of the theory of the technological field. The views of the interviewees regarding the characteristics and the future of marine energy production depend on their positions within the field. To be more precise, Chapter 8 is dedicated to the analysis of the ‘frontiers’ of the field, i.e. of the way it relates to other socio-technical loci such as the financial sector, other technological fields and UK’s culture in general. The most interesting finding is that the field of marine energy technology forms uneasy relations with all these other social loci¹. Technological development in the field of marine energy depends on whether or not the investors from the private sector will provide funding and economically weaker agents do not approve of this relation. Other technological fields that are more

¹ The term ‘social locus’ is used in this thesis as a generic term referring to every possible meaningful association of socialized human beings.

established, such as for example the wind energy field, serve as sources of know-how for new and innovative fields such as the field of marine energy. Thanks to the existence of these fields, the agents of the field of marine energy do not have to start from scratch and perform all the necessary societal innovations themselves. At the same time, however, each technological field competes with others for funding and personnel. Moreover, I will show that several interviewees claimed that public support towards technological innovation was not always certain in Scotland.

The description of its relations with other socio-technical loci, are the first step towards the understanding of the field of marine energy. However, in Chapter 9 I show that the technological field is not a social locus that is entirely determined by its relations with other sectors. The agents of the field do not compete only for financial capital but instead have instituted two types of capital which can be found only within technological fields. This is a common element of my approach and Bourdieu's (2001) and I have to point out that each technological field has its own proper versions of these two types of instituted capital. These types of capital are bureaucratic capital and technological capital. With the term 'bureaucratic capital' I signify all the skills that guarantee a successful accomplishment of bureaucratic tasks within the field. Agents, who work in higher positions in the institutions of the field, tend to

possess a larger amount of bureaucratic capital and can usually innovate more efficiently when faced with specific bureaucratic problems. Nevertheless, being a good bureaucrat is not the only thing necessary to the agents of the field. They have to know how to correctly handle technological artefacts so that they can be capable of inventing new ones and, hence, develop technological innovations. These skills comprise the second type of instituted capital which has developed in the field, i.e. technological capital.

The answer to question four, i.e. the institutional question is completed in Chapter 10 which describes the impact of the organisation of the field of marine energy to a technological entity, i.e. a technological process which will determine to a large extent the future development of the sector. This process is the speed of proceeding from small to large multi-megawatt devices and whether or not this should be done rapidly or modestly. The most important conclusion of this chapter is that the views of the interviewees depend on their positions in the field and that these differences in their views has led them to perform different technological innovations which rely on distinct business plans in terms of funding and organisation.

Finally, the only question that was not answered in the first ten chapters of this research project is Question 5, i.e. the provision of policy advice. Chapter 11, i.e. the concluding chapter of this thesis makes the

first tentative steps towards providing an answer. It also attempts to explain why this approach, the theoretical framework of the technological field can be useful to many different categories of people, such as for example policy makers, the agents of the field themselves and ordinary citizens. For the latter, the approach of the technological field could help democratise technological change without imposing many constraints on the innovating process.

Chapter 2: The Theoretical Foundations of the Technological Field

The aim of this chapter will be to start addressing research question one, i.e. the ontological question, and hence to lay the foundations of this social scientific enquiry by developing an ontology of technological change as a social phenomenon. What makes this nevertheless difficult in the case of technological innovation is the omnipresence of technology and innovation in human societies. It is one of the defining features of humanity which separates it from other living species (Oakley, 1972). The difficulty becomes even greater considering the fact that any social activity related to technology results in changes into entities that are not strictly social in the sense that they have an important material dimension (MacKenzie and Wajcman, 1985). The omnipresence and materiality of technology and technological change are the reasons why there are many different theoretical understandings of technology and technological change to choose from. Hence, I had to develop specific criteria which determined which social scientific theories would be the most relevant to my research project.

To find these criteria, I started from a common understanding of the role technology plays in human society:

“According to Collins English Dictionary (1979), technology is (1) the application of practical or mechanical sciences to industry or commerce; (2) the methods, theory and practices governing such application; (3) the total knowledge and skills available to any human society for industry, art, science, etc.” (Grint and Woolgar, 1997, p. 8)

This extract includes the first key characteristic of technological entities, i.e. the ‘craft’ aspect of technology. Using the term technology, researchers and lay people alike, often refer to knowledge that is applied to specific artefacts by skilled craftspeople or scientists in order to achieve specific goals in the fields of industry, art or science. Technology is understood as the combination of artefacts and methods about how to use them. Any theory of technological innovation should explain how technologists obtain and use the know-how about the construction and use of these artefacts. The first criterion is exactly to evaluate theories which provide such accounts.

Nevertheless, social scientific investigation has revealed that technological innovation is much more than a craft. In the following extract, Batteau described technology as a phenomenon which consists of many aspects, only one of which is craft:

“A starting point for understanding the relationship of technology and culture is to appreciate that “tool” and “technology” are quite separate concepts. “Tools”—plows, digging sticks, knives—are about usefulness, and in most cases do encapsulate social relationships. “Technology” is also useful, most of the time, but condenses some new

dimensions of cultural meaning: words, standards, connections, capability, insight, and aesthetics. Technology is both a large-scale system of imperative order and a collective representation specific to modern societies. Technology is a project of civilization, or more precisely civil-ization: bringing civil or corporate order to chaos.” (Batteau, 2010, p. 2)

Here, Batteau suggested that once the concept of the artefact and its use is separated from the concept of technology, it is possible to understand technology as a mode of representation akin to a specific society, i.e. as an entity that creates specific ways to encounter, understand and interact with reality. And, at the same time, it is the medium through which this specific representation system and its logic expands. Actually, ‘many sociologists see technology as the impetus for the most fundamental social trends and transformations’ (Sassen, 2002). Hence, technological change is not simply the development of specific crafts, but, on the contrary, the development of crafts according to types of reasoning which can be found/are predominant in a specific society. Therefore, the second criterion I used was to find theories which provided insight into how technology reflects specific types of reasoning and helps expand their application.

However, knowing that technological innovation is the construction and use of a new artefact and at the same time the expansion of a specific kind of reasoning does not provide an answer in the question of the ‘nature’ of such change. Technological change can be

equivalent to any other kind of change that occurs in nature (for example if a dog moves, it changes its location in a space) and society (whenever a different party wins the elections, the living conditions of the poor change), or a completely different type of change.

Aristotle defined what the ancient Greeks called *techne*, i.e. the arts and crafts, as an imitation of nature (Castoriadis, 1978). This view defined the way European societies acknowledged many types of human creations, such as art and technological artefacts for the last two millenniums. This reasoning considered human creations, as ‘images’ of eternal, created by God or nature ideal models and it was a reasoning which corresponded to a society willing to perpetuate a specific way of existence. As the West progressed to modernity, this reasoning retreated and it was replaced by the following, as described by Blumenberg and Wertz (2000, p.47):

“The devaluing of nature is thus not simply a nihilistic process, because it becomes possible to believe that "what is visible is but a fragment of the whole, there being many more latent realities," and that this world "is not the only possible world." Thus art no longer points to another, exemplary being, but rather it itself is this exemplary being for the possibilities of humanity: The work of art no longer wants to mean something; rather, it wants to be something.”

In this extract, the authors argued that in modernity, human creations, such as art, stopped being considered imitations of nature or derivatives

of a divine order. Instead, the aim is to construct something original and different. If this reasoning is applied to the domain of technology, it leads to a technocratic society that regards technological advancement as something valuable per se (Postman, 1992).

This discussion led me to the conclusion that my approach should be able to understand technological innovation as a creation of something original and different that changes both the artefacts themselves and—possibly—the predominant reasoning within a society. Technological innovations represent a ‘break’ from what is considered usual within a society. However, technological innovations are changes that refer to the whole process of the inception realisation and adaptation of a new idea into a pre-existing socio-technical reality which consists of an already instituted world characterised by specific types of material culture, which humans use without even noticing (Ortega y Gasset, 1934; Winner, 1977). Everything that is considered ‘stable’ in human lives, such as, for example, our everyday practices would be inconceivable without specific types of technology. Hence, stability is equally important as change. The third criterion suggests that I should evaluate theories capable of theorising and understanding both stability and change.

All the theories I evaluate in this chapter, address these three issues. Their successful points and their shortcomings can be used as

building blocks in order to theorise successfully technological innovation. However, many theories have already directly attempted to analyse the phenomenon of technology. Their contribution was not neglected since I believe that any piece of research has to engage in constructive dialogue with pre-existing literature in its sector, even more so if pre-existing literature does comment upon the criteria chosen by the researcher.

This chapter will be divided into four sections, each containing theories which address the three criteria in distinct ways. The theories are categorised according to the way they interpret the second criterion, i.e. the type of reasoning followed by technological change and have been chosen so as to reflect the different approaches to the understanding of society which appeared during the last three centuries, as social scientific investigation emerged, developed and diversified. I chose to categorise the theories according to the way they address the issue of the relation between the reasoning of technological development and the reasoning of societal change. If technology is the impetus for social stability or change, then this relation could be the key to the understanding of technological change I try to develop. The first section will deal with approaches that recognise a degree of rationality in the way technological development unfolds, whereas the second will deal with approaches that negate this. The third section will investigate how

already existing approaches to technology dealt with the phenomenon of technology, rational or not. The final concluding section will serve as a bridge that articulates all the contribution of the critical evaluation of these theories in order to proceed to Chapter 3 where I will construct an innovative theoretical approach to technological change.

2.1 Rational Technology

2.1.1 Rational Choice Theory

Rational choice theory appeared in the 18th century and it was one of the first social scientific approaches that argued that technology evolves according to a reasoning. To be more precise, its supporters claimed that it evolved rationally through the work of technologists who were capable of ranking and classifying their desires rationally. Agents made their choices only after carefully considering how many of their desires they could satisfy given their income constraints (Galbraith, 1987). If humans lived under a regime that allowed for the exercise of this type of rational calculations, they would be able to construct a socio-economic system capable of constantly improving the standards of living of the majority of people. They claimed that this socio-economic system was modern capitalism which was capable of enhancing the lives of the

human agents who lived under its influence in many different ways including through the production of more and more diverse technological artefacts (Smith, 1776; Solow, 1956). This diversity was the outcome of the standardisation of aspects of the innovating process in the domains of science and technology, as can be seen in the following quote which describes the standardisation of specific aspects of the innovation process, as one of the main reasons why Europe succeeded in developing faster during the industrial revolution:

“But if I had to single out the critical, distinctively European sources of success, I would emphasize three considerations:

- (1) the growing autonomy of intellectual inquiry;
- (2) the development of unity in disunity in the form of a common, implicitly adversarial method, that is, the creation of a language of proof recognized, used, and understood across national and cultural boundaries; and
- (3) the invention of invention, that is, the routinization of research and its diffusion. ” (Landes, 1998, pp. 200-201)

Moving on, the reason why rational choice theorists considered capitalism capable of improving the standards of living through the use of technology, was that, in capitalism, technology was the determining factor of a firm’s or an economy’s production function. It was the factor that specified which types of combinations of inputs and outputs were potentially feasible, as can be seen in the following quote from an economist, i.e. a member of a scientific sector which strongly supports

rational choice theory:

“The simplest and most common way to describe the technology of a firm is the production function which is generally studied in intermediate courses...A firm produces from various combinations of inputs. In order to study firm choices we need a convenient way to summarize the production possibilities of the firm, i.e., which combinations of outputs and inputs are technologically feasible.” (Varian, 1992, p.1)

Even though this definition accurately explained that human agents can make rational choices about outputs and inputs, given a specific type of technology, it unfortunately did not allow researchers to infer how they could choose the type of technology itself. Thus, to understand technological change, it is necessary to hypothesise some types of changes in the production function.

To express these changes in the production function, many microeconomists (Nicholson and Snyder, 2008), macroeconomists (Keynes, 1936) and economic growth theorists (Solow, 1956) applied in their models production functions which included a parameter that represented technology. Hence, technological change was a change in its value, an external negative/positive shock of indeterminate origins, the roots of which were not sufficiently understood. However, this was simply a good example of black-boxing the rational character of technological change within free market economies. This is why, authors

such as Romer (1990) decided to provide technology with its own production function which defined it as an output of many other input factors such as capital, labour, human capital (Benhabib and Spiegel, 2005) and already existing knowledge (Corrado et al, 2013).

Even if this solution did allow rational choice theorists to argue that the rationality of technological change in a free market economy was not entirely unjustifiable, the main deficiency of rational choice theory was its inability to understand the craft aspect of technology. Rational choice theorists treat a problem that is both quantitative and qualitative as something that pertains only in the first of these categories. The reason is that the foundations of rational choice theory's argumentation about rationality lie in the assumption that human agents are utility maximising entities with ad hoc preferences which have not been determined at any extent by the way they interact with their environment (Mill, 1848; Pareto, 1906). However, social scientists such as Collins, while describing a component of technological innovation, namely experimental science, argued that local conditions matter:

“Some scientists can do certain experiments while others cannot. We might say that this could be because the latter are bad at hand-eye coordination or related skills; it might be, because the unsuccessful scientists do not have the right equipment or specimens to hand; or it might be because they lack tacit knowledge.” (Collins, 2001, p.72)

Under this perspective, rational choice theory leaves little space for the development of an understanding of an idiosyncratic phenomenon such as the ‘craft’ of the people which depends on the conditions of the locations in which it has been developed.

Nevertheless, understanding that rational choice theorists underestimated the craft aspect of technological change led me to another conclusion. If technology has its own production function, then anyone can see that it is treated as just one more resource, one more type of capital that can be used to produce other goods. The only difference is that some aspects of this type of capital, such as non-tacit knowledge, are non-rival in the sense that they can be used simultaneously (Romer, 2006, p. 116) by more than one agents. If they regard technology as a resource, however, rational choice theorists have promoted a static, non-historical understanding of innovation. They neglected the ‘break’, the disruptions that the qualitative characteristics of each technological innovation might cause, not only on the production function, but also on everyday life. They appreciated technology’s existence and function as a background of a given socio-technical environment but they avoided the examination of how and when humans try to change it to radically alter this environment.

There is a second current among rational choice theorists that attempted to solve the ‘riddle’ of technological change. During the

second half of the 20th century and moving away from mainstream economics, some rational choice theorists supported the view that human rationality was bounded and path-dependent. This economic approach was partially inspired by the epistemology of Kuhn (1962) who argued that scientific development occurred within distinct and competing paradigms. However, the greatest influence in their work was the approach of Schumpeter (1939) who, instead of considering technology as a given dimension of the production function, famously argued that technological innovation was a derivation of the entrepreneur's profits and had a catalytic effect on the economy.

Thus, a new theory arose that claimed that technological innovations depended on previous innovations, i.e. there were specific types of technological trajectories (Dosi, 1982) which followed specific technological paradigms, a concept which was equivalent to Kuhn's (1962) scientific paradigms:

“In broad analogy with the Kuhnian definition of a "scientific paradigm", we shall define a "technological paradigm" as "model" and a "pattern" of solution of selected technological problems, based on selected principles derived from natural sciences and on selected material technologies.” (Dosi, 1982, p. 152)

Within a technological paradigm, the rationality of the human agent, entrepreneur and/or engineer was bounded, i.e. it was allowed to

evaluate only specific future possibilities. That way the approach of bounded rationality managed to understand the craft aspect of technology. Craft could be described here as human capital obtained via work along a specific technological paradigm:

“More precisely, if the hypothesis of technological paradigm is to be of some use, one must be able to assess also in the field of technology the existence of something similar to a "positive heuristic" and a "negative heuristic". In other words a technological paradigm (or research programme) embodies strong prescriptions on the directions of technical change to pursue and those to neglect.” (Dosi, 1982, p. 152)

Therefore, bounded rationality theorists managed to understand the impact qualitative characteristics had upon technological change. The success of a specific technological innovation was due either to the fact that it was ‘located’ on an already successful trajectory or to the fact that it was itself the starting point of a new trajectory. The reasons for its predominance therefore were mostly financial: the expansion of an innovation was a result of the fact that it was profitable given the technological path of the society in which it was introduced (Freeman and Perez, 1988).

Bounded rationality can highlight the institutions that have to be taken into account to understand an innovation: they can provide a better understanding of the ways firms and financial institutions influence the

success of technological innovations. However, just as all other economists, its supporters firstly describe humans as beings with ad hoc preferences, and secondly recognise in the face of technology only the means to achieve an end. Hence, they do not escape the one-sided static understanding of other economists and find it difficult to describe the factors that were critical for the first stages of an innovation, especially of those that introduce new technological trajectories.

2.1.2 Rational Sceptics: Marx

Rational choice theorists were ineffective in understanding technological innovation as craft and disruption, exactly because they consider the preferences and desires of human agents as independent from their income constraints (Marshall, 1920). Without assuming this independence, they would have to accept that the instances of cooperation and competition that occur in the everyday life of the producers of new types of technology do influence their innovations. Perhaps then I should abandon the assumption that socio-technical reality becomes objectively more and more rational and instead I should pay more attention to the interests which are served by the increased rationalisation of technological change under capitalism. Hence, in this section, I will depart from rational choice theory in order to comment on

the contribution to the understanding of technological change offered by theoretical approaches which emerged during the 19th century and doubted the claim that modern institutions were always destined to progress and become less and less problematic.

Karl Marx, the inventor of historical and dialectical materialism during the middle of the 19th century, situated the craft aspect of modern technological innovation in the struggle between the classes of the dominating bourgeoisie and the controlled proletariat, both as a component and as an outcome (Marx, 1867). Marx can be described as a ‘theoretical anti-humanist’ and this does not mean that he did not uphold the values of humanism. This characterisation refers to the fact that he supported the theoretical stance that located the determining factors of human history not in the human subject per se but in class struggle, i.e. the conflict between the capitalist relations of production and capitalism’s productive forces (Althusser, 1975). Hence, it was class struggle that shaped the valorisation process of production which then conditioned the technology applied in each sector of the economy (MacKenzie, 1984).

Given the preponderance of class struggle and its institutions, as they evolved historically, what determined which type of craft would develop is the interplay between the interests of the capitalist ruling class and the capacity for resistance of the proletariat. Indeed, in the first

volume of *Capital*, Marx argued that the main motive behind the application of new machinery, i.e. of new technology, was the extraction of surplus-value from the workers:

“John Stuart Mill says in his *Principles of Political Economy*: ‘It is questionable if all the mechanical inventions yet made have lightened the day’s toil of any human being.’ That is, however, by no means the aim of the application of machinery under capitalism. Like every other instrument for increasing the productivity of labour, machinery is intended to cheapen commodities and, by shortening the part of the working day in which the worker works for himself, to lengthen the other part, the part he gives to the capitalist for nothing. The machine is a means for producing surplus-value.” (Marx, 1867, p.492)

Hence, the producers of technology will become masters of the craft of developing technological innovations which decrease the control of the proletariat over the production process by deskilling their labour (Braverman, 1974) and by increasing its degree of alienation. Alienation is, after all, one of the most decisive instruments of controlling the workforce:

“With the increasing value of the world of things proceeds in direct proportion the devaluation of the world of men. Labor produces not only commodities: it produces itself and the worker as a commodity-and does so in the proportion in which it produces commodities generally. This fact expresses merely the object which labor produces -labor’s product- confronts it as something alien, as a power independent of the producer. The product of

labor is labor which has been congealed in an object, which has become material: it is the objectification of labor. Labor's realization is its objectification. In the conditions dealt with by political economy this realization of labor appears as loss of reality for the workers; objectification as loss of the object and object-bondage; appropriation as estrangement, as alienation.” (Marx, 1844, p. 71)

If innovation is one more way of extracting surplus value, then it is no surprise that Marxist analysis sustains the view that the innovations that succeed are those that render the control of the (increasingly alienated from their work) proletariat easier. These innovations are favoured by the ruling classes and avoid the destiny of being shelved unlike other innovations ‘friendlier’ to the proletariat. After all, technological innovation possesses such an impact upon the prices of stable and variable capital, that it can even avert the tendency of the capitalist rate of profit to fall due to any potential shortage of labour (Sweezy, 1942, pp. 96-108).

Hence, from the viewpoint of the proletariat, technological development under capitalism is not rational at all. Under these conditions, once an innovation is incorporated within the production process, the proletarians in their turn try to become masters of the craft of ‘taming’ it, i.e. of working in ways which neutralise its features that render their control more effective (Mackenzie, 1984). Taming applies equally to individual innovations and clusters of innovations that shape

specific systems of industrial organisation such as for example those that constitute the assembly line. The inability to continuously increase the level of control over the work force under a specific industrial system (and hence to continually increase the level of surplus value extracted under this regime) is the reason why capitalists have to innovate and radically alter the model of production as a whole from time to time: Taylorism was succeeded by Fordism and then by neo-Fordism (Aglietta, 1976).

Marx (1867) argued that, even though workers resist to their technologically induced control, technological change under capitalism still has a ‘crystallising’ effect. Maintaining its control over the production process becomes a more and more hopeless task for the proletariat, whereas capitalists can intensify their control over continuously increasing amounts of personnel. As Marx (1867) illustrated in the first volume of ‘Capital’, workers are better controlled under the regime of mechanised production than under the regime of manufacture:

“In manufacture the organisation of the social labour process is purely subjective: it is a combination of specialized workers. Large-scale industry, on the other hand, possesses in the machine system an entirely objective organisation of production, which confronts the worker as a pre-existing material condition of production.” (Marx, 1867, pp. 507-508)

This crystallising effect however, does not impose limits only on the workers, but also forces capitalists to compete more intensely. Capitalists cannot reduce the level of control exercised upon the workers, because they will be out-competed by their competitors:

“Hence the capitalist who applies the improved method of production appropriates and devotes to surplus labour a greater portion of the working day than the other capitalists in the same business. ... The law of the determination of value by labour-time makes itself felt to the individual capitalist who applies the new method of production by compelling him to sell his goods under their social value; this same law, acting as a coercive law of competition, forces his competitors to adopt the new method.” (Marx, 1867, pp. 436-437)

The more intense the competition is, the more rapid the adoption of new methods by capitalists becomes. This conclusion bears important consequences for the contemporary globalised world because competition is more intense than ever (e.g. see Almunia, 2013).

If Marx was correct, it is not surprising that during the latter years of the 20th century, the years of globalised competition, it is difficult for political forces, which adhere to a cooperation or compromise of the classes, to impose any type of reduction of the control exercised over the proletariat by capitalists. The latter cannot agree to any such plan if they want to avoid getting overrun in the intensely competitive late modern world. Perhaps this is one of the main causes

why capitalists have been described as being out of control by local powers in the late modern globalised world (Bauman, 2000, p. 153). This is why social-democrats have sought to discover alternative ways to overcome the harshest impacts of capitalism (e.g. see Giddens, 1998).

However, it is here that the second peculiarity of the rational technological development under capitalism becomes obvious. From the viewpoint of capitalists, technological development is rational if it increases their control over their workforce and the acquisition of surplus-value to an extent larger than their competitors'. From the viewpoint of capitalism as a whole Marx argued that this type of socio-technical development leads to an exploitation of the vast majority of the population (i.e. of the proletariat) to an extent that there are not sufficient customers with enough income to purchase the goods produced by capitalists:

“Contradiction in the capitalist mode of production. The workers are important for the market as buyers of commodities. But as sellers of their commodity –labour-power – capitalist society has the tendency to restrict them to their minimum price.” (Marx, 1885, p.391)

According to Marx, capital's incapacity to circulate easily will ultimately lead to a discrepancy between the level of development of the forces and relations of production:

“The productive forces at the disposal of society no longer tend to further the development of the conditions of bourgeois property; on the contrary, they have become too powerful for these conditions, by which they are fettered, and as soon as they overcome these fetters they bring disorder into the whole of bourgeois society, endanger the existence of bourgeois property. The conditions of bourgeois society are too narrow to comprise the wealth created by them.” (Marx and Engels, 1848, p. 215).

In the end, capitalism collapses and a vast number of socio-technical innovations take place which will form part of a new social system, socialism (Marx and Engels, 1848; Lebowitz, 1976).

Marxist analysis is to some extent capable of providing an understanding of technological change along the lines already discussed. It does manage to understand innovation as a break that has to come to terms with socio-technical reality. It acknowledges technology’s role as a resource that shapes and stabilises the form of social phenomena and maintains pre-existing social order whilst appreciating its role in revolutionising society and shaping new realities (Marx and Engels, 1848). Its account of the various forms of competition and class struggle, offers a very specific way to understand which craft will be preferred and pursued by the capitalists (the one which increases the extracted surplus-value) as well as instructions about the reason why some innovations will not be simply incremental changes but instead will change for ever the face of one or more economic sectors (the inherent limits to the

expansion of control of the workforce which exist in any industrial system). Moreover, Marxism offers a clear explanation of the differences between technological change before and during modernity, as well as a reason why the latter is so much more rapid. It is the competition among capitalists in terms of more advanced technologies that compels modern societies to innovate more and more (Aglietta, 1976).

However, even though Marxist theory provides an answer to some of the topics discussed earlier, this answer is not entirely satisfactory. Marxism offers a macroscopic view of the history of technological change. The problem with this view is that one of the main and ever-present characteristics of craft under capitalism for the proletarians, i.e. alienation, does not have to apply to the entirety of the producers of technological innovation. It is possible to hypothesise the existence of niches within a technological sector where people who innovate are either subject to a lesser degree of alienation or develop types of craft with idiosyncratic types of alienation. Hence, perhaps the emphasis should not only be on the dynamics at the macro level of the world economy but also on the dynamics of the specific social loci where innovation takes place; for example, as Latour and Woolgar (1986) did in the case of scientific laboratories. Furthermore, it is difficult to predict beforehand the impact of some innovations to the control of the proletariat, in which case, Marxist analysis is not so efficient when there

is a need to explain innovations that do not make already existing production processes cheaper but instead create entirely new economic sectors, such as for example sectors of need formation as described by Thrift (2005). Finally, Marxist analysis of technology suffers from economism (Mouzelis, 2008), i.e. all social phenomena are attributed to the conflicts which take place at the level of the production process. Technological change however might be critically influenced by other human institutions besides those which handle the economic issues.

2.1.3 Rational Sceptics: Weber

Unlike Marx, Weber never abandoned ‘theoretical humanism’. According to his theorisation, developed during the end of the 19th century and the start of the 20th, the ultimate root of all social phenomena, including craft, is the human subject and its actions (Weber, 1947). Using the human agent as a starting point (Giddens, 1971), Weber described the true rational spirit of the modern age, i.e. that of the predominance of what he calls *zweckrationalität* (Weber, 1947.), i.e. rationally oriented action, that of the disenchantment of the world and that of the expansion of rational bureaucracies (Weber, 1919). However, even though he did analyse modernity, Weber did not try to develop a theoretical approach specifically destined to understand technological

innovation. To understand his view of it, I will have to rely on the theoretical principles of his work and on the various references to this phenomenon found throughout his work.

Weber claimed that researchers should refrain from considering history a process which evolves according to the dictates of one single factor, such as Hegel's Spirit or Marx's class struggle. Instead, the causal factors behind a social phenomenon, including the craft aspect of technological innovation can be revealed only after a laborious scientific procedure:

“But it is, of course, not my aim to substitute for a one-sided materialistic an equally one-sided spiritualistic causal interpretation of culture and of history. Each is equally possible, but each, if it does not serve as the preparation, but as the conclusion of an investigation, accomplishes equally little in the interest of historical truth.” (Weber, 1905, p. 125)

Hence, any one-sided causal interpretations of social phenomena and human history such as economism and culturalism should be rejected. Instead researchers should accept the harsh reality of researching in a complex world with a plurality of determinant factors of human behaviour. This plurality of determinant factors gets narrower the more researchers move away from research at the societal level to researching more specific phenomena. After all, this is one of the primary functions of science: to develop an understanding of the motivations that lurk

behind specific actions of humans (Weber, 1904).

So, what kinds of motivations lurk behind technological innovation? Weber, in the *Theory of Social and Economic Action* (Weber, 1947, p.163), posited a very strong link between technology and the economy:

“The fact that what is called the technological development of modern times has been so largely oriented economically to profit making is one of the fundamental facts of the history of technology. But however fundamental it has been, this economic orientation has by no means stood alone in shaping the development of technology... None the less, the main emphasis at all times, including the present, has lain in the economic determination of technological development. Had not rational calculation formed the basis of economic activity, had there not been certain very particular conditions in its economic background, rational technology could never have come into existence.”

Hence, Weber accepted that there is one determining factor of technological change that supersedes (but not excludes) all others, i.e. the economy and economically oriented human behaviour. Hence, understanding technological development is impossible without an understanding of the economic behaviour of humans in each given society and time period. Another conclusion would be that to understand technological development during modernity, researchers have to take into account the rules and characteristics of market economy, and the economically rational behaviour that agents are forced to adopt therein.

The next step then is to find a way to develop an understanding of economic behaviour.

In page 158 of the same book, Weber defines economically oriented action and economic action in the following way:

“Action will be said to be ‘economically oriented’ so far as, according to its subjective meaning, it is concerned with the satisfaction of a desire for ‘utilities’ (Nutzleistungen). ‘Economic action’ (Wirtschaften) is a peaceful use of the actor’s control over resources, which is primarily economically oriented. Economically rational action is action which is rationally oriented, by deliberate planning, to economic ends.” (Weber, 1947, p.158)

This passage includes three definitions each of which envelopes the next. Economically oriented action is any human action which deals with the satisfaction of the desire for utilities and is understood, designed and pursued as an effort to satisfy this desire by the human agents which undertake it. Within the larger category of economically oriented action, strictly economic action is every economically oriented action which makes peaceful use of the resources available to the agent undertaking it. Finally, economically rational action is any economic action the targets and methods of which are chosen rationally.

The emphasis on the peaceful use of the actor’s resources ‘forced’ Weber to explicitly distinguish economic action from what he would call in English technology or techniques. Therefore, according to Weber,

technology differed from economic action because:

“Economic action is primarily oriented to the problem of choosing the end to which a thing shall be applied; technology, to the problem, given the end, of choosing the appropriate means.” (Weber, 1947, p.162)

These definitions of economic action and technology make a clear and straightforward distinction between the two which resembles the one found in rational choice theory. Technology is the means to achieve the end which is chosen by economic action. Researchers who try to understand specific types of economic behaviour have to firstly describe how human agents chose their ends given their resources, and secondly to narrate an account of the ways in which human agents will use their resources to achieve their ends. Weber (1947) claimed that the adequate way to perform this two-step procedure was to conceptualise an ideal type, i.e. an abstract model of the standardised behaviour of an economic agent which performed specific acts.

Hence, in his analysis, according to the definition of economic action, an economic agents' choice of an end is related to the resources he or she possesses when she or he chooses these ends. These resources however are nothing else but the means to achieve a given end, i.e. nothing else but the technology, according to Weber's definition, to achieve this end. The understanding of an agents' economic action

depends on the previous understanding of the technology available to this agent and to the ways she or he obtained it and relates to it. Similarly, according to Weber's definition of technology, it is impossible to understand technology and technological development if researchers do not take into account the ends towards which the means are used. Technology is the use of some resources for the achievement of a given end; hence, it would be very difficult to understand unless these ends and the reasons why these were chosen and not others are described and understood. And obviously these ends depend on the economic action of the agents.

It is clear that economic action determines the ends and technology determines the means for their achievement. The understanding of economic action depends on the understanding of the ways each agent relates to their resources. The latter, however, depends on the understanding of economic action. What that means is that the researcher is unable to understand the shaping of technology and economic action simultaneously. However, this is exactly the case when humans perform a technological innovation. A technological innovation is the development of a new resource. To understand it, the economic end for which the new resource is developed has to be described. But the economic end depends on previously existing resources (the description of which depends on previously existing economic ends of the agent

herself or of other agents) and on the capability of the agent to perform this specific innovation. This type of circular reasoning does not allow for a proper understanding of the craft aspect of technological innovation and for the description of the ideal type of the ‘technologist innovator’.

Weber’s inability to understand technological change leads to many side-effects regarding his approach’s understanding of social phenomena. Weber (1905) postulated that economically rational action leads to the creation of more and more rational bureaucratic procedures which dominate more and more dimensions of human lives. This is a process that will ultimately force human agents to spend their lives within a socio-technical reality as rigid as a steel-made shell:

“The Puritan wanted to work in a calling; we are forced to do so. For when asceticism was carried out of monastic cells into everyday life, and began to dominate worldly morality, it did its part in building the tremendous cosmos of the modern economic order. This order is now bound to the technical and economic conditions of machine production which to-day determine the lives of all the individuals who are born into this mechanism, not only those directly concerned with economic acquisition, with irresistible force. Perhaps it will so determine them until the last ton of fossilized coal is burnt. In Baxter’s view the care for external goods should only lie on the shoulders of the “saint like a light cloak, which can be thrown aside at any moment”. But fate decreed that the cloak should become an iron cage.” (Weber, 1905, p.123)

Therefore, Weber did not believe that humanity’s future under modernity would be bright. Instead, Weber pointed out that the expansion of

rational bureaucracies could potentially lead to the loss of the individual's autonomy and to a regime of utter domination (Alexander, 2013). Unlike in Marx (1867), the cause of this phenomenon is not class struggle over the control of the forces of production but the expansion of the 'capitalist spirit', i.e. the spirit of rationalisation and individuation, the origins of which lie in a variety of economic and cultural factors, which have to be examined and evaluated by social scientists. Within this context, it is certain that he considered technology a phenomenon that obliged human agents to behave in specific ways. Therefore, there is the danger that what started as a force which rationalised and disenchanting the world, as well as increased the individuation and autonomy of the individual, would in the end, via technological change, lead to an expansion of a regime of domination imperceptible as a transparent cloak but one which dominated nevertheless (Weber, 1905).

However, if Weber inexorably linked technology with the fate of human societies within modernity, it is exactly this fate that some authors considered the blind spot of Weber's approach. For example, Collot-Thélène (1990) argued that the inescapability of the 'iron cage' meant that Weber in the end was unfaithful to his own ontological proposition of the existence of a plurality of determining factors of socio-technical phenomena, since within modernity everything could be understood as the result of the expansion of rational bureaucracies. Similarly,

Alexander (2013) claimed that Weber did not clarify the potential exits from the iron cage of modernity, because he did not explain how the expansion of rational bureaucratic institutions and the adherence to ethical values could coexist:

“Weber’s sociology indicates that in modernity destructive moments can be overcome, but it does not explain how. The overcoming has not been random, nor has it depended on the contingency of individual courage alone. There were structural reasons which can be sociologically explained... Weber argued that scientific rationality and ethical values should coexist, but he did not identify the conditions under which such a coexistence might be achieved.” (Alexander, 2013, p. 50)

If technological innovations are the ones which augment the crystallising effect of technology and rational bureaucracy, it is easy to understand that it is the potential deficiencies explained previously in Weber’s account of technological change that rendered him unable to clarify how it is possible to escape from the iron cage. Perhaps, had he managed to move beyond a reductive understanding of technological change as means to an end, he would have been able to explain how it is possible to escape from the ‘iron cage’.

To sum up the evaluation of Weber’s analysis, researchers have to firstly see which are the useful aspects of his theorisation and secondly what could be learned from the analysis of its deficiencies. The most valuable aspect of his approach is that by arguing in favour of a plurality

of causal forces within human history he on the one hand avoided developing a reductive account and on the other managed to find a clear location for the empirical research in the study of social phenomena. Secondly, Weber clearly demonstrated the special characteristics of modern institutions and highlighted the importance of the understanding of their function to the emergence of a theory of technological change and its impact on society.

And yet, Weber did not manage to understand the other side of technological change. His understanding of technology is one of a resource and this is the ultimate reason why he can understand technology only within a given economic reality and why he failed to uncover the exit from his iron cage. This is the reason why his ideal type did not apply in the case of the technologist innovator. Understanding technology as a resource, as the means to achieve an economic end, is a static understanding of a phenomenon that represents 'a break' perhaps better than any other.

2.1.4 Middle-Range Theory.

The three previous approaches suffered from deficiencies which hindered their understanding of technological innovation. Researchers such as Boudon (1991) argued that these deficiencies were due to the

fact that rational choice theorists, Marx and Weber felt the need to develop overreaching ‘grand’ theories. However, socio-technical reality is so complex that any ‘grand’ theory will be obliged to leave many misunderstood or unexplored ‘black holes’. To hide these cases of inefficient theorizing, grand theories have to develop reductive concepts defined as the ultimate source of everything that cannot be understood within these frameworks.

Even if the quest for the ‘grand theory’ might be futile, by the middle of the 20th century, a new approach emerged, which proposed to promote methodological pluralism based on theoretical frameworks and concepts designed to understand local phenomena and not the entirety of socio-technical reality. These theoretical constructions were supposedly situated between the grand theories and the strictly empirical investigation and were called middle-range theories (MRT thereafter) (Merton, 1957). Their purpose was to identify and depict patterns within specific local phenomena from which researchers could extract variables whose associations could be described by models. Through the division of socio-technical reality into separate loci, MRT offers the opportunity to combine more than one theory in order to explain complex phenomena (e.g. see Geels and Schot, 2007; Pollock and Williams, 2008). That way, it is possible to avoid the high level of abstraction that is the greatest deficiency of grand theories.

An example of the application of MRT in the domain of technological change is the model of the relation between expectations and technology (Van Lente and Rip, 1998; Brown and Michael, 2003). This model predicts that innovation depends on the craft of technologists to cultivate the expectation of investors and other social institutions that they will obtain large benefits, if they support their innovative projects. The technological innovations are realised within a cycle of making promises – obtaining support – delivering on these promises. If the third step of this process does not take place for whatever reason, then:

“...repair work is performed. Actors give reasons for delay and make new promises that are more specific, refined and detailed. This results in 'promise-requirement cycles' (Van Lente and Rip, 1998) that can be continued as long as there is sufficient progress to legitimate new promises and as long as sponsors continue to believe them.” (Geels, 2007, p.636)

However, it is not evident that such models can really be less abstract than ‘grand theories’. The combination of different theories for the explanation of a phenomenon could increase the level of abstraction since there is the problem of incommensurable propositions. Even if such a combination of different theories does not take place, still the models of MRT rely on the theoretical position that it is always possible to clearly define ‘*theoretical scope*’ (Geels, 2007, p.628) according to which reliable models are less abstract than grand theories. This

theoretical position however is itself a ‘grand’ theory as abstract as any other. It is difficult to understand which would be the correct ‘middle’ level of abstraction. For example, it is unclear whether research concerning the market of marine renewable energy in Scotland is located at the middle range or if it is too abstract and researchers should focus on the individual developer firm of wave energy devices.

2.2 Non-Rational Technology

2.2.1 Heidegger

The previous approaches described the reasoning of technological change as more or less rational even if this rationality can be understood only at the middle range. Here, I focus on theories which denied the rational character of technology and did not describe it as means to an end. During the first half of the 20th century, a new approach appeared which argued that envisaging technology as means to an end was nothing but an illusion which forbade social researchers from understanding the true essence of technology. A prominent figure among this category of theorists was Martin Heidegger.

Heidegger's evaluation of technology can be found firstly in an elementary form in his monumental work *Being and Time* (Heidegger,

1927) and secondly in a more complete form in his later work *The Question Concerning Technology* (1954). In *Being and Time* Heidegger (1927) confronted for the first time the phenomenon of technology by describing two ways in which humans could experience tools, such as a humble hammer. Firstly, there was *zuhandenheit* which has been translated as ‘handiness’ or as experiencing the hammer as ‘ready to hand’. It is a practical understanding of a tool by a human which already possesses the craft of using it and does not contemplate its characteristics, relations with other entities or other qualities but instead focuses on how it is possible to act with it:

“The less we just stare at the thing called hammer, the more we take hold of it and use it, the more original our relation to it becomes and the more undisguisedly it is encountered as what it is, as a useful thing... We shall call the useful thing's kind of being in which it reveals itself by itself *handiness [Zuhandenheit]*. It is only because useful things have *this* "being-in-themselves," ["An-sich-sein"] and do not merely occur, that they are handy in the broadest sense and are at our disposal... When we just look at things "theoretically," we lack an understanding of handiness.” (Heidegger, 1927, p. 69)

Only when a tool does not work due to a malfunction are humans forced to experience a thing in a theoretical way, i.e. by noticing and interacting with all its characteristics and the relations it can develop. This type of experiencing things like the hammer is called by Heidegger *vorhandenheit*, i.e. experiencing it as present-at-hand. This type of

experience is founded upon handiness, as can be seen in the following quote from an important commentator of Heidegger, Ihde:

“And Heidegger's strategy in *Being and Time* is to show that these are not merely two alternate modes of relation, but that one is founded upon the other, in this case the "present-at-hand" upon the "ready-to-hand". This is, in effect, an action theory of ontology.” (Ihde, 2010, p.44)

In his later work, Heidegger explored the implications of this understanding of tools within modern socio-technical reality where there is a preponderance of technological artefacts. In *The Question Concerning Technology* (Heidegger, 1954) handiness becomes the main way of experiencing the world. This dominance of human living experience by things ready-to-hand ultimately induces human agents to *enframe* (Gestell) socio-technical reality. Enframing means to experience everything as standing-reserve, i.e. as a resource which has to be exploited via the application of instrumental logic:

“Enframing means the gathering together of the setting-upon that sets upon man, i.e., challenges him forth, to reveal the actual, in the mode of ordering, as standing-reserve. Enframing means the way of revealing that holds sway in the essence of modern technology and that is itself nothing technological.” (Heidegger, 1954, p. 227)

The whole rationale of the modern age is to impose enframing as the main way of experiencing socio-technical reality, to an extent that

technology eventually enframes even humans:

“As soon as what is unconcealed no longer concerns man even as object, but exclusively as standing-reserve, and man in the midst of objectlessness is nothing but the orderer of the standing-reserve, then he comes to the very brink of a precipitous fall; he comes to the point where he himself will have to be taken as standing-reserve.”
(Heidegger, 1954, pp. 231-232)

Hence, Heidegger argued that technology was one of the ways through which the domination of man proceeded. Humans have been reduced to entities which experience things only as resources to be exploited. Modern societies treat everything as an object that will have to be used (Heidegger, 1938). They are blind to all the other ways of experiencing socio-technical reality and they are unable to exercise any type of thinking other than that which is dictated by this specific way of revealing things as standing-reserves.

Since Heidegger (1927) insisted on the ontic and ontological priority of *dasein*, i.e. of the temporal character of the subjectivity of the subject, it is not surprising that he argued that enframing was perhaps the greatest danger that humanity faced. As a consequence, humans should try to discover how to avoid this way of experiencing socio-technical reality. And the way out he proposed was experiencing the world through art:

“Because the essence of technology is nothing technological, essential reflection upon technology and decisive confrontation with it must happen in a realm that is, on the one hand, akin to the essence of technology and, on the other, fundamentally different from it.

...

Such a realm is art. But certainly only if reflection on art, for its part, does not shut its eyes to the constellation of truth after which we are questioning” (Heidegger, 1954, pp. 237-238)

Thus, Heidegger’s (1927, 1954) main contribution is that he was the philosopher of modernity who reflexively revealed one of the most important functions of modern technology. In many cases he was fundamentally correct about the way technological innovations were incorporated into pre-existing socio-technical reality. Technological innovations are firstly funded and then used as an instrument to achieve a specific purpose and they lead human agents to experience socio-technical reality as an accumulation of resources to be used by whatever institutions control them.

The problem however, is that Heidegger offered a type of ‘one size fits all definition’, which did not cover many different methods through which technology intervened in the way humans experienced the world. In their everyday lives, humans had and still have to coexist with so many different types of technological artefacts and processes, so that technology intervenes in all their actions. The same was true for Heidegger when he wrote ‘The Question Concerning Technology’. He

was obliged to use various objects such as the pen, the paper and the typewriter. Hence, it would be inaccurate to suggest that it always reveals the world as a standing-reserve (Ihde, 2010). It did not stop Heidegger from developing a type of ‘craft’ which allowed for a present-at-hand understanding of Being. And if this was possible in the case of Heidegger, then it is also possible in the case of technologist innovators.

Overestimating the primacy of *zuhandenheit* is a deficiency that rendered Heidegger’s approach unable to understand the initial stages of technological change. At the local level, a technologist that tries to discover new technological artefacts might experience socio-technical reality in radically different ways than as standing-reserve. *Vorhandenheit* could emerge regardless of *zuhandenheit* and there is a possibility that an innovating process might be fascinating and, hence, experienced, to use Heidegger’s words (1954, p. 237), as a ‘bringing-forth of the true into the beautiful’, just as a work of art. Finally, if each age has its own way of experiencing the world via technology, any understanding of the latter has to include an account of the way this specific type of experiencing the world emerged from a previous and distinct era. Unfortunately the ‘one size fits all’ narrative of Heidegger, did not achieve this.

2.2.2 Technology Beyond the Human Subject

As I moved from rational choice theory to Marx, Weber and eventually Heidegger, technology possessed a more and more ontologically important role in the constitution of socio-technical reality. It is now time to make one more step towards this direction and argue that humans are not the protagonists of humanity's technological history. An influential (Wyatt, 2008) theorising of this type in modern societies is technological determinism, i.e. the theory which claims that technology's development (MacKenzie and Wajcman, 1985) is the product of an internal reasoning of pre-existing technological artefacts and that human agents are nothing but a component of this inner mechanism. The craft of this 'component' is limited to the accomplishment of the dictates of pre-existing machines. For example, the invention of the steamship was an inevitable development because some pre-existing technologies (such as the steam engine) had already been part of socio-technical reality. Furthermore, technological determinism is a key ingredient of any popular and not necessarily academic view that technological development will lead humanity to a dystopian future. Such views can be found even in academia and the natural sciences (e.g. see Hawking, [2014])

Since technology develops through an inner reasoning

(MacKenzie and Wajcman, 1985), technology determines society and society is only a reflection of what is allowed and prohibited by technology. The invention of the automobile determined modern consumerist urban culture which would not have existed in any recognisable form had cars not been part of human lives. Social phenomena are the ultimate result of technological phenomena and neither human agents nor institutions or other types of social structure can escape this influence, a rather dark conclusion regarding the fate of human liberty.

Influenced by the preponderance of technology in modern societies, in the early 20th century, theorists such as Oswald Spengler (1918) and (a little later) Jacques Ellul (1954), have claimed that specifically in modern societies technology has escaped human control:

“Every conscious being today is walking the narrow ridge of a decision with regard to technique. He who maintains that he can escape it is either a hypocrite or unconscious. The autonomy of technique forbids the man of today to choose his destiny... In the past, when an individual entered into conflict with society, he led a harsh and miserable life that required a vigor which either hardened or broke him. Today the concentration camp and death await him; technique cannot tolerate aberrant activities.”
(Ellul, 1954, p. 72)

The absence of control of technological development will ultimately lead to the decline of human societies (Hughes, 2004) since humans are

unable to control their fate through scientific enquiry. In fact science itself has been transformed into technoscience, as can be seen in the following quote:

“If truth is what is verifiable, the truth of contemporary science is not so much the extent of progress achieved as the scale of technical catastrophes occasioned. Science ... has developed solely with a view to the pursuit of limit performances, to the detriment of any effort to discover a coherent truth useful to humanity. Modern science, having progressively become technoscience...has slipped its philosophical moorings and lost its way...” (Virilio, 1998, p. 1)

Technoscience does not provide truths but only rapid technological innovations. Hence, it cannot help those humans who would like to change their fate through knowledge.

Technological determinism, however, does not fulfil any of the criteria cited at the start of this chapter. It is certainly an account that does not underestimate (quite the contrary) the stabilising effects of technological artefacts analysed by Marx (1867) and Weber (1905), but at the same time it has a view of human agents as simple carriers of the dictates of artefacts. However, it is difficult to think of socio-technical reality as the locus where the creator is entirely defined by its creations. This story is one more representation of technology as a static background of human history that neglects its function as the target towards which human agents work to achieve a break and create a new

reality. What's more, if the being of each innovation is determined, as the result of past technological artefacts, it is uncertain at which level the researcher has to locate the initial point of an innovation. Such a belief is neither able to understand the starting and ending points of an innovation nor capable of discriminating among nature and culture as well. Not knowing where to start from an investigation renders technological determinism incapable of articulating a methodology for the empirical investigation of specific technological innovations.

Another theory that does not envisage the human subject as a protagonist of technological change is Michel Foucault's post-structuralist approach. To Michel Foucault, a self-proclaimed follower of Nietzsche (Sluga, 2010), technological artefacts, as well as society as a whole, were not shaped by the thoughts, aspirations and actions of the human agent. Foucault (1969) reduced the human subject to a canvas destined to be painted by the predominant discourse of each society and/or human era, specifically by the continuous accumulation and scattering of discursive statements which determined which actions and/or other statements were possible. Foucault claimed that modern discourse was a discourse in which power had a capillary form (Mouzelis, 2008) and imposed technologies of control upon the human body which led to its subjection (Foucault, 1975). The Foucauldian term 'technologies' however does not refer to the technological artefacts and

processes the change of which this research aims to understand. Instead it is a collection of more or less material practices which constitute and shape what is usually described as the human subject:

“Foucault spoke of different types of technologies: technologies of production, which permitted individuals to produce, transform, or manipulate things; technologies of sign systems, which permit us to use signs, meanings, symbols, or signification; technologies of power, which determine the conduct of individuals and submit them to certain ends or domination; and technologies of the self.”
(Tovar-Restrepo, 2012, p.104)

Among those more or less material practices, can be found entities that modernity's discourse presents as ‘objective’ such as science (Foucault, 1963), highly personal functions of the human body such as sexual behaviour (Foucault, 1976), and the various types of craft that produce technological artefacts and technological innovations with the meaning that I have attributed to these terms.

However, shaping the body and mind of the human agent is not necessarily a peaceful process where everything occurs only after the human agents have expressed their consent. Instead Foucault (1975) insisted that this was a process that included various oppressive ways of ‘convincing’ the bodies and minds of the agents to adopt specific behaviours. Foucault argued in *Discipline and Punish* (1975), that technological entities and their development in modern societies played a

key role in the achievement of the subjection of humans by the modern discourse of power:

“In fact, the two processes – the accumulation of men and the accumulation of capital – cannot be separated; it would not have been possible to solve the problem of the accumulation of men without the growth of an apparatus of production capable of both sustaining them and using them; conversely, the techniques that made the cumulative multiplicity of men useful accelerated the accumulation of capital” (Foucault, 1975, p.221)

Therefore, technology’s contribution to the subjection of humans is a very significant factor that has to be considered in my innovative approach. Foucault’s (1975) work is very important in this respect because he allowed for the existence of types of power and conflict, different from those described by Marx (1867), within the process of technological innovation which nevertheless were key determining factors of the ways this process took place.

To present a more precise Foucauldian understanding of modern technology, I will have to describe contemporary technological artefacts as entities which reassure the perseverance of panoptical institutions. The panopticon is a metaphor that Foucault (1975) utilised to explain the function of the modern discourse of power which shaped institutions that became more and more complete, austere and prison-like, and took its name from the description of a prison which consisted of a large tower in

the centre that established the easy surveillance of the cells located in the periphery. The cells in their turn rendered the communication among prisoners impossible (Foucault, 1975).

The panopticon is a laboratory, where the exercise of power can be perfected and expanded. The reasoning of panopticism, even though it has nothing to do with rationality as e.g. the rational choice theorist would describe it, does allow for the constant enhancement of the exercise of control and the expansion of predictable behaviours of human agents and technology:

“But the Panopticon was also a laboratory; it could be used as a machine to carry out experiments, to alter behaviour, to train or correct individuals. To experiment with medicine and monitor their effects. To try out different punishments on prisoners, according to their crimes and character, and to seek the most effective ones. To teach different techniques simultaneously to the workers, to decide which is the best.” (Foucault, 1975, p.204).

This laboratory that tends to penetrate the minds and souls of those subjected to control is a mechanism that once applied, can function on its own. This means that the application of panopticism is an efficient response to any type of challenge within socio-technical reality no matter the local conditions (Foucault, 1975). Power can penetrate everywhere and proves to be very efficient in imposing its style of existing.

Even so, the main deficiency of this theorisation of technology is

that Foucault (1975) presents modern discursive power as an ever-present force that determines everything including the human subject and its material environment. However, if everything is a derivation of discourse, then the way this discourse changes remains a mystery. Envisaging humans as subjects to the universal power of panoptacist institutions and describing technological artefacts always as means to the end of the continuous expansion and penetration of power are not very different from the description of technology and labour in the clearly modern approaches of rational choice theory and Marxism. After all, how did the modern discourse of power emerge as the defining and predominant discourse of modernity if both every human and every technological artefact with which they interacted were a product of the qualitatively different discourse of the Middle Ages for example? Why did modern discourse replace the traditional and why are panoptacist institutions more effective and capable of expanding on their own once they are applied? The inability to provide answer to those questions hindered Foucault's capability to understand the 'breaks' that technological innovations delivered. Instead the determination by the modern discourse of power with its panoptacist characteristics became a 'one size fits all' explanation, as can be seen below:

“When Foucault, in *Discipline and Punish*, talks about "discipline" in the singular tense ... indeed gives the

impression that he entraps himself when presenting the panoptical scheme not as an example among others but as a sort of universal model which can be applied, starting from the special case of the prison, to other disciplinary institutions like the army, the school, the laboratory, the hospital etc.” (Macherey, 2012, pp. 69-70, my translation from the Greek)

The expansion of panopticism became an explanation that could be applied to any phenomenon and did not provide insight about how this discourse changed.

Foucault (1969) acknowledged this deficiency in his theorisation, admitted that he was unable to find out if discourse was generated by discursive formations or vice versa (for example see Mouzelis, 2008) and, through the study of human sexual behaviour in his last works (Foucault, 1984), tried to develop a more complex description of how the discourse of power determines human subjects. However, these efforts remained incomplete and, even though his post-structuralist approach did open new paths towards the understanding of the function of modern institutions (the ‘discovery’ of new types of power and the articulation of a critique of modernity) his failure to account for the diverse ways of co-existence between humans and technology signified the limits of approaches which relegated the human subject to a mere product of an ever-present force. I can understand Dews (1987) who accused Foucault of not providing an understanding of the entity that was oppressed and shaped by power. And if a naïve understanding of the human subject as

determinant force of socio-technical reality is definitely not what I am looking for, perhaps the correct way forward is to examine the diverse and qualitatively distinct ways of interaction between humans and their material environment.

2.2.3 Complexity Theory

Perhaps the final step towards the non-rational was taken by the supporters of Complexity Theory. Complexity theorists see a world the Being of which is complex, i.e. a world that is dominated by non-linearity (Urry, 2003), and radical relationality (Dillon, 2000). The former means that both ‘social’ and ‘natural’ phenomena display disproportionality between causes and effects: insignificant causes produce substantial effects. Complexity theorists move as far as declaring that the qualities of a macro structure cannot be reduced to the qualities of the entities that compose it. Non-linear phenomena allow for the emergence of new qualities in socio-technical (Urry, 2003; Cilliers, 2005), and natural phenomena (e.g. see Capra, 2005). The predominance of radical relationality means that neither ‘social’ nor ‘natural’ entities can exist or be defined separately from their relations with other entities. Hence, the distinction between nature and society or culture is meaningless (Urry 2006, p. 113):

“Complexity repudiates the dichotomies of determinism and chance, as well as nature and society, being and becoming, stasis and change. Systems are thus seen as being ‘on the edge of chaos’. Order and chaos are in a kind of balance where the components are neither fully locked into place but yet do not fully dissolve into anarchy. Chaos is not complete anarchic randomness but there is a kind of ‘orderly disorder’ present within all such systems.”

The assemblages of relations behave as open systems which exist on the verge between entirely predetermined and entirely random evolution along a non-reversible arrow of time that renders historical both social and natural laws (Cilliers, 2005).

It is evident that Complexity theory overcomes the dichotomy between nature and society and does not underestimate their impacts on any phenomenon, including technological change. Equally, Complexity theorists are capable firstly of understanding the characteristics and differences of the craft of technologists as they appear in modern and pre-modern cultures and secondly of distinguishing phases of modernity conceived by other theorists, such as liquid modernity (Bauman, 2000), and knowing capitalism (Thrift, 2005). Hence, they can study the technological aspects of the transition between these phases. On the other hand, their support for a complex Being of the world obliges them to insist on their knowledge claims being modest (Cilliers, 2005):

“When dealing with complexity, modest positions are inescapable. This does not imply that they should be relative, vague or self-contradictory, nor does it imply a reason to cringe in false modesty. We can make clear, testable assertions about complex systems. We can increase the knowledge we have of a certain system, but this knowledge is limited and we have to acknowledge these limits.” (Cilliers, 2005, p. 263)

Hence, within a complex system, knowledge claims can only be limited and localised. Different approaches to investigate a topic will lead to distinct conclusions.

Furthermore, in a complex world, where any least cause can have infinite consequences, technoscience and its theoretical foundations are not simply representational, but have performative or counter-performative effects as well (Thrift, 2007). It is the performativity of the theories that craftspeople adhere to that determine in the end which innovation will take place. This is a shared conclusion among Complexity theory and the various versions of constructivism (e.g. see MacKenzie, 2004; Callon, 1998).

Nevertheless, if Complexity Theory claims that knowledge can only be limited, it is rather strange to suggest that this principle does not apply to the epistemology of Complexity theory itself. If knowledge always has to be limited (Cilliers, 2005), Complexity Theory fails to be reflexive. What applies to other knowledge claims does not apply to Complexity Theory itself. Furthermore, if knowledge claims are

localised, it is unclear how localised they have to be and it is difficult to distinguish a local from a global knowledge claim. For example, it is uncertain how modest researchers should be regarding a knowledge claim which accepts the existence of global warming due to carbon emissions (Urry, 2010). Does it depend on the starting point of the research? Moreover, epistemological modesty does not have to be derived from an adherence to a complex Being. The starting point could be an ontological position in favour of a vague and only partially approachable Being. If the term 'complex' refers to a non-linear and radically relational reality, then knowledge claims should be allowed to be local, universal or entirely false, depending on the knowledge claim and the 'region' of Being to which this knowledge claim was addressed. Similarly, technoscientific performativity might exist or not depending on the 'region' of Being and is not an ever-present characteristic of technoscience. The incapability to identify the loci of reality, where technoscience is performative, and to distinguish local from universal knowledge claims, undermines its capability to understand technological change.

2.3 Past Understandings of Technology

2.3.1 Social Construction of Technology (SCOT)

This chapter concludes with the analysis of two approaches which explicitly aimed to provide an understanding of technology and technological change. The first of these two approaches was initially designed to understand science. SCOT aka the Social Construction of Technology (Pinch and Bijker, 1984) claims that technology and its evolutions are socially negotiated and determined. SCOT originated from the approach of social constructivism that was first applied to the domains of science and the human knowledge. This approach, based on the epistemology of Kuhn (1962) and his competing scientific paradigms, claimed that scientific theories, even the most abstract such as mathematics, were a social construction, the result of negotiation and agreement among human agents and social groups (Barnes et al., 1996). Each scientific theory was replaceable as soon as examples that did not fit into its paradigm rendered necessary a renegotiation whose result would be a new agreement and a new scientific paradigm. The only entity that was not treated as a social construction was the human ability

to separate and categorise diverse phenomena. The evaluation of scientific theories should not be a restricting expression of awe due to the truth they expressed: scientific theories should be evaluated according to specific criteria that guaranteed their objectivity (Bloor, 1976, p.7).

These criteria are:

- Causality: researchers should be able to give an account of the reasons why there is a specific scientific belief or explanation.
- Impartiality: researchers should not discriminate between different types of beliefs and try to explain all of them, no matter how irrational, false or 'weird' they seem.
- Symmetry: to explain a specific scientific claim, researchers should use the same types of explanation, regardless of how true or false it is considered in the present.
- Reflexivity: The reasoning applied to other scientific beliefs should be able to explain the claims of the sociology of scientific knowledge as well.

SCOT is an effort to adapt social constructivism to the domain of technology. Just as agents and social groups negotiate the validity of different scientific theories, SCOT claims that different social groups negotiate the final form and function of technological artefacts. This negotiation can be a short or long process and at its end technological artefacts find their final form and function, i.e. *closure* is achieved. After

closure, the negotiation stops and the new technological artefact becomes part of the unquestionable technological background of the society (Pinch and Bijker, 1984). However, this incorporation into the background of the society does not mean that other forms and functions of the artefact were impossible in the first place. The classic example, which Pinch and Bijker (1984) used, is the example of the bicycle, the final form of which ensured that it would be stable and safe for all categories of users, including women and over-aged people. However, before the achievement of closure there were some other types of bicycles, such as one with a large front wheel which was designed for greater speed, but was much more unstable.

SCOT's approach can easily satisfy the first three criteria mentioned previously. The reason for the predominate form and function of a technological artefact is the influence of diverse social groups. Different forms and function of specific artefacts need not be discriminated against since every type of artefact is the result of the negotiations of social groups and there is no 'natural' shape of each artefact. Furthermore, the same reasoning, i.e. the negotiation among social groups is applied for the explanation of many diverse forms of an artefact.

SCOT's conformity to the fourth criterion, reflexivity, is trickier, a problem that can be found in any type of social constructivism, even in

the case of the study of scientific knowledge. Many researchers have accused social constructivism of needing itself another meta-theory that would justify the constancy of its claims compared to the knowledge claims the construction of which it examines:

“sociological analysis... is faced with an irresolvable dilemma.... Findings cannot be regarded as valid until we have satisfactory methodological theories. But [these] are no different in principle from other sociological theories [in that] they... need the support of firm methodological theories. We appear, therefore, to be caught in an infinite regression which effectively prevents any form of intellectual advance.” (Mulkay, 1974, p.118)

Others have accused social constructivists of engaging in ‘ontological gerrymandering’. What that means is that they examine and juxtapose the differences among the definitions that many distinct groups of scientists give to a phenomenon that the social constructivists consider as possessing constancy, without examining under the same terms the knowledge they themselves claim to use, i.e. the claim that the phenomenon is characterised by a degree of constancy:

“The metaphor of *ontological gerrymandering* suggests the central strategy for accomplishing this move. The successful social problems explanation depends on making problematic the truth status of certain states of affairs selected for analysis and explanation, while backgrounding or minimizing the possibility that the same problems apply to assumptions upon which the analysis depends... some areas are portrayed as ripe for

ontological doubt and others portrayed as (at least temporarily) immune to doubt.” (Woolgar and Pawluch, 1985, p. 216)

Regarding technology, Woolgar (1991) argued that, to be reflexive, technological artefacts had to be envisaged as scripts and, hence, all their potential understandings, including those that were technologically deterministic, those that argued in favour of their social construction and the understanding of the reflexivist social researcher who argued in favour of such an equal and symmetric treatment had to be treated as equally valid and important.

The ultimate result of this approach however is to treat as a construction even the researcher's view that the technological artefact is something different from any other text:

“But where does this get us? Does not this confusion of subject and object (the author as technology; the technology as text) merely muddy the analytic waters? Yes! That is exactly the objective!” (Woolgar, 1991, p. 42)

This is not however, really a reflexive response to the phenomenon of technology, because Woolgar confused two different things: the simple interaction between humans and technological artefacts, during which humans have to develop a theoretical or practical knowledge of the artefact on the one hand, and the determination of the characteristics, form and function of new technological artefacts on the other, for which

both technological determinism and SCOT (Pinch and Bijker (1984) are talking. Woolgar might have adequately demonstrated that any types of beliefs about an artefact including the one that claims that the artefact is something different from the researcher and the one that is written in this text were equally a constructed text but unfortunately he did not perform any enquiry about how and why this specific set of artefacts-texts referring e.g. to the car was constructed and not any other. Only the latter enquiry could show if SCOT is reflexive or not.

SCOT argues that the form and function of technological artefacts depend on the views and interests of related social groups and the negotiations among them. The Being of technological innovations is always a derivation of these views and interests. If researchers really want to understand a technological development, they must first try to understand the views of relevant social groups. This assertion leads to the question of how the views of these social groups were formed. If a social constructivist wants to adhere to the criterion of reflexivity (Bloor, 1976) mentioned earlier, the reasoning applied to technological innovations should be able to explain the formation of social groups as well. However, in the case where social groups are the result of the negotiation among other social groups, it is very difficult to determine which negotiation among social groups is the starting point of an innovation. For example, it could be the one that led to the construction

of the artefact or the one that formed the groups that negotiated this construction. To state it more clearly, constructivists have not described the starting point of the construction.

Unable to respect the criterion of reflexivity, SCOT does not provide a sufficiently satisfactory understanding of technological change. It is true that some theorists have tried to suspend the importance of not complying with the criterion of reflexivity (Ashmore, 1989). However, in the case of technological change this deficiency is of paramount importance, because the views of social groups might be a product of other social structures or institutions (such as for example the Marxist social classes [Russell, 1986]) or of diverse practices of craft. SCOT is unable to provide an account of the impact of such structures. On the one hand, it is true that its emphasis on empirically researching the specific conditions and negotiations that shape each innovation offer the opportunity to escape the one-sided understandings cited so far and, at the same time, retain modernity's high praise of scientific methods; but, on the other hand, its preferred methodology does not allow for a sufficiently rich understanding. However, elements of this approach could be used as building blocks for an improved understanding: the already mentioned emphasis on the empirical research, the tendency to support the local focus of the research and the tendency to focus on the impact of created human institutions to innovations (even though the

latter is limited to the vaguely understood category of ‘social groups’).

2.3.2 Actor-Network Theory (ANT)

Another theory that has offered a central analytical role to technology is Actor-Network Theory (ANT thereafter). ANT aims to provide an understanding of technology founded upon the position of a flat ontology that its proponents adopted after they relocated Bloor’s (1976) principle of generalised symmetry from the epistemological to the ontological level. That means that ANT aims to understand all entities within socio-technical reality under the same terms and neglects the diversification of emergent socio-technical loci as can be seen in the following quote from one of its critics:

“ANT therefore presents what critical realists would call a flat ontology in not just one but two respects: in addition to its neglect of realities beyond the empirical domain, it also strives to ignore the existence of emergent social structures.” (Elder-Vass, 2008, p. 465)

A flat ontology implies firstly that the participation of technological entities in the formation of socio-technical reality or, as Actor-Network theorists frequently put it, of ‘outthereness’ (Law, 2004), is of an identical importance with the participation of humans and should be analysed under the same terms. The distinct qualitative characteristics of

humans, i.e. the fact that they are potentially reflexive beings who can think and develop crafts which will ultimately lead to innovations, does not render them worthy of a 'special treatment' within ANT's understanding of socio-technical reality: all entities, human, natural or technological have unique characteristics and human subjective experience is just one of them.

This is the reason why technology is so important to ANT. After all, technology 'justifies' at the ontic level ANT's choice to ignore the limits between nature and culture and, instead, to pay attention to the imbroglios formed by humans, natural and technological entities (Latour, 1999). In fact, the proponents of ANT propose social scientists to avoid both the technical and the social determination of socio-technical reality and instead describe how these imbroglios form (Latour, 1988). A more accurate way to describe these imbroglios would be the term 'Actor-Network' from which ANT took its name. ANT theorists deploy this term because it expresses the way they envisage every entity within socio-technical reality. Everything is a network formed via associations of actors who are networks themselves, formed via associations of other actors.

Within a socio-technical reality consisting of actors-networks, technological artefacts are the entities via which humans associate with other entities and people. To be more precise, technological artefacts

intervene to translate an action that requires much effort into something that requires less effort and hence, are the key for the formation of human-related networks:

“I will define this transformation of a major effort into a minor one by the word translation or delegation; ... As a more general descriptive rule, every time you want to know what a nonhuman does, simply imagine what other humans or other nonhumans would have to do were this character not present. This imaginary substitution exactly sizes up the role, or function, of this little figure.” (Latour, 1988, p.299)

It is the impact of these non-human actors-networks or ‘actants’ as Latour (1988) called them that sociology ignores and this is the reason why he described them as the ‘missing masses’ of a discipline that is completely dominated by social determinism (Latour 1992). Technology, just as every other entity, including socio-technical reality as a whole, should be understood as an actor and a network at the same time, which consists of associations of other smaller-scale actors-networks and participates in the formation of other actors-networks. Researchers should stop treating technology in a modern way, i.e. as an external, morally neutral force of socio-technical reality and should instead try to uncover the impacts it has as it forms and dissolves various networks. Technology should not be considered as the means to achieve specific other ends, but as ends which form new networks and dissolve any pre-

existing ones and therefore shape new realities (Latour, 2002).

Actor-Network theory provides an extremely detailed description of the interactions among humans and non-humans in a given phenomenon. Unfortunately, if researchers try to develop an understanding of technological change things become much trickier. Technological innovations are timely processes and necessitate a starting point, where they emerge for the first time. However, ANT theorists do not clarify if the starting point of a technological innovation such as an innovative AIDS vaccine, is to be found at the level of the individual researcher, the level of the neurons in his/her head, the level of the institution in which this researcher is working, the behaviour of the HIV virus or medicine as a whole. Which is the correct Actor-Network? All these entities just cited are actors-networks and ANT is very good at depicting their relationships once they are formed but is unable to uncover the creation of the links among them.

ANT's incapability to locate the starting point of technological innovation implies that it cannot understand that different rearrangements of the associations within a specific Actor-Network generate qualitatively distinct results. Hence, it concludes that the analysis of every actor-network should take place under the same terms and that all actors-networks are qualitatively identical. They are composed by actants and the qualitative differences of their associations

are considered identical or remain unexplored. This is the reason why Actor-Network theory is unable to distinguish between different cultures, nature and culture and modernity and pre-modernity (Latour 1991):

“No one has ever been modern. Modernity has never begun. There has never been a modern world. The use of the past perfect tense is important here, for it is a matter of a retrospective sentiment, of a rereading of our history. I am not saying that we are entering a new era; ... No, instead we discover that we have never begun to enter the modern era. Hence the hint of the ludicrous that always accompanies postmodern thinkers; they claim to come after a time that has not even started!” (Latour, 1991, p.47)

Under this perspective, it is not surprising that Latour (1988, 1992) insisted on describing mundane technologies: ANT is better suited to analyse technological actants that are not subject to rapid change, something that its proponents would otherwise be obliged to examine and evaluate. In a sense, in terms of the understanding of technological change, ANT is much more modern than its creators would wish it to be. The lack thereof of an understanding of the ‘roots’ of the qualitative characteristics of a change renders it unable to examine the break within socio-technical reality that a technological innovation *induces*.

2.4 Summary

This chapter consisted of a critique of past socio-theoretical approaches, designed to provide me with the components of a theory capable of developing an effective understanding of technological innovation. I attempted to evaluate these approaches in terms of whether or not they can provide an account for each of the three aspects of this understanding, i.e. for craft, specific reasoning and change vs. stability. Alas, it is the fate of critique to seem more rejecting than accepting of the object of its critique. However, my aim was not to simply reject the theories thus far presented, but rather to use them and their critique as building blocks for the theoretical approach which I will present in the next chapter. Now, I would like to summarise these building blocks.

The chapter started with an examination of theoretical approaches to technological change which claim that this phenomenon envelops rationally. The first approach, rational choice theory, argues that this rationality is objective, even if in some cases it is bounded, whereas the other three approaches, i.e. Marxism, Weber's and MRT argue in favour of recognising distinct types of limits to the rationality of technological change. Marxism claims that technological change is rational only under the perspective of the capitalist system, Weber posited that technological

change would encase all human relations within a shell as hard as steel and MRT rejects the possibility of a grand theory and recognises phenomena susceptible to rational analysis and modelling only at the middle range.

The contributions of these approaches to my theory vary. Rational choice theorists and bounded rationality aficionados successfully argue that a prerequisite for the understanding of technological change is the understanding of the structure and function of capitalist firms and of their interactions in the market. Technology and innovations are used distinctively in capitalist institutions which have to out-compete other firms and differently from pre-modern institutions. However, they fail to develop an understanding of the different types of craft which emerge due to the interactions between the preferences of human agents and the environment in which they learn and work. Marxism on the other hand, through its descriptions of competition and class struggle can provide insight regarding the types of craft which emerge and hence the causes of the generation of new technological paradigms. Be that as it may, it suffers from economism, and hence, it does not evaluate sufficiently the existence of firstly non-economic ultimate causes of specific phenomena, and secondly of idiosyncratic locales where the macroscopic conditions of socio-technical reality, do not apply. And this later factor is exactly what I took from MRT: a

reminding that an understanding of technology necessarily has to be able to evaluate the local and recognise that the local level is not always determined from the macroscopic level. Equally, Weber provides an account that rejects both economism and culturalism and acknowledges the existence of a plurality of causal factors of human behaviour and the need to develop an understanding of the human subject to avoid reductive explanations (Weber, 1905). This is a very important building block of my approach, unlike his failure to disentangle the relation between economy and technology.

The second part of this chapter tried to focus on theoretical approaches which negated the rationality of technological development. This part started with Heidegger's rejection of the understanding of technology as means to an end, and the exposition of his phenomenological approach that envisages technology as a force which enframes humans. It continued with the critique of technological determinism which argues in favour of technology developing according to an internal logic, and of the approach of Michel Foucault who understands technological change as a derivation of the modern discourse of power which takes place via the expansion of panoptical institutions. It finished with the presentation of the argumentation of complexity theory which envisages technological innovations as performative enactments of technoscience.

Heidegger's contribution is invaluable to my research because he successfully argued that any understanding of technological innovation should remember that the human agents who engage in the craft of technological innovation do not engage and interact with it only theoretically but practically as well, even if in the end he failed to uncover the links between these two types of relating to technological entities. Furthermore, Foucault helped me realise how crucial it is to examine the various types of control that appear in the innovating process and shape both the bodies and minds of the agents therein as well as the artefacts that they handle and produce, even if he failed to develop this himself for the case of technological entities. The contribution of technological determinism was to remind me that there are inherent limits to the ways via which humans can handle specific material entities. Finally, complexity theory has shown to me that in order to understand change and the breaks that innovations induce, it is necessary to theorise the phenomenon of performativity of specific types of relation between humans and other material entities and to understand the source of this performativity, something that complexity theorists did not try to do.

The final section of this chapter was dedicated to the evaluation of two contemporary evaluations of technology, i.e. of SCOT and ANT. Even though they both originate in the strong programme of sociological

studies of science, they understand technology in radically distinct ways. The former emphasised to me the importance of understanding the processes of negotiation among various institutions which shape technological artefacts and the necessity to be reflexive in my research. The second contributed via ‘blurring’ the theoretical frontier between society and nature. Hence, by abandoning any preconceptions about the strict distinction between society and nature, I was able to focus on the identification and theorisation of what is or is not susceptible to humanly induced change.

Each of these contributions should be included in an innovative understanding of technological innovation. However, a new theoretical approach to this phenomenon cannot be a patchwork of all these arguments, because a simple combination of more than one theory leads to the problem of incommensurable propositions. What has to be done, instead, is to develop an innovative approach capable of incorporating all these arguments, whilst being founded upon a clear and concise theoretical base. This is what I do in the next chapter, where I conclude my answer to the ontological question.

Chapter 3: Radical Creativity and the Technological Field

In this chapter, I will use the conclusions of the previous chapter to construct a new approach which will include the strengths and avoid the weaknesses of the theories presented previously. By the end of this chapter I will have presented a new ontology of technological innovation and completed the answer to research question one, i.e. the ontological question. The theory I present satisfies the three criteria presented in the previous chapter. It will start with the presentation and critical evaluation of the theoretical approach of Pierre Bourdieu (1972) and the concepts of the *field*, *habitus* and *cultural capital*. Bourdieu argued that social phenomena took place within social loci called fields in which a regulated struggle was observed among agents who—guided by the dispositions they acquired within the field, i.e. their habitus—competed for diverse forms of symbolic ‘rewards’, i.e. cultural capital (Bourdieu and Wacquant, 1992). I will argue that the concepts of the field and cultural capital could contribute significantly to the understanding of the craft aspect of technological innovation and to the reasoning its development follows. To be more precise, they address successfully many of the key ingredients of this approach, discussed in the previous chapter. On the contrary, the habitus does not help develop an adequate understanding of the ‘break’ that technological innovations induce within

socio-technical reality.

Since the break that innovations cause is the most elusive aspect of technological innovation, the second part of this chapter will attempt to solve this problem using the theorisation of Cornelius Castoriadis. I evaluate Castoriadis's position (1975) in favour of a non-ensamblist-identitary Being of socio-technical reality, his argument that humans are capable of ex-nihilo creation and his concept of social imaginary significations, and I present his understanding of technological change. Ex-nihilo creation can be a key idea for the understanding of rupture and change. However, Castoriadis' understanding of the interactions between radical imagination and social imaginary significations is unable to answer the question of how and why the specific qualitative characteristics of crafts and technological innovations emerged and not others.

The final part of the chapter will merge the critiques of Bourdieu and Castoriadis and present the main concepts of my innovative understanding of technological innovation. These are *radical creativity*, a concept designed to overcome the shortcomings in Castoriadis' understanding of the radical imagination and Bourdieu's (1980) habitus and the *technological field*, i.e. the part of socio-technical reality which is inhabited by radically creative agents who form relations of cooperation, competition and clientage, and deal with the development

of technological innovation

3.1 Bourdieu

Bourdieu's aim was to develop a theory which could overcome the contrast between objectivism and subjectivism, i.e. the contrast between the impact external structures have on human behaviour on the one hand and human action on the other (Brubaker, 1985). Bourdieu addressed the issue through the development of a theory of practical action which takes place within competitive fields of power (Calhoun, 2013). Using this framework, he managed to address successfully many of the necessary elements of an understanding of technological change, such as economic interests, class struggle, power and control, negotiations among specific institutions within specific social formations and the frontiers between society and nature.

However, Bourdieu was parsimonious in his references to technology, even when he wrote texts that seemingly referred to technological artefacts (Sterne, 2003) such as *Men and Machines* (Bourdieu, 1981) and *On Television* (Bourdieu, 1996). Even then he preferred to focus on the social relations that developed around these artefacts, something that differentiated him significantly from social constructivists who intended to interpret the impact of the society upon

the artefacts themselves. I think that this parsimony is misleading, because he belongs to the category of social theorists (e.g. Giddens, 1984; Bourdieu, 1980) who argued that practical learning was a more important determining factor of human behaviour than what humans learned reflexively, or at least that practice was ontologically as equally significant as discursive interactions (Archer, 2001). In that case, technology is important in the work of Bourdieu because it would be impossible to develop practices without interacting with technological artefacts.

In the core of Bourdieu's (1972) theorisation lays an understanding of social reality as the accumulation of a number of inter-dependent loci where human agents develop several distinct types of practices. Bourdieu called these loci 'fields' and started the description of any type of social behaviour by describing the characteristics of the field in which the agents under examination participated (for example see the application of this rule to himself in Bourdieu [2004]). As he put it:

“A field is a structured social space, a field of forces, a force field. It contains people who dominate and others who are dominated. Constant, permanent relationships of inequality operate inside this space, which at the same time becomes a space in which the various actors struggle for the transformation or preservation of the field. All the individuals in this universe bring to the competition all the (relative) power at their disposal. It is this power that defines their position in the field and, as a result, their strategies.” (Bourdieu, 1996, pp. 40-41)

Bourdieu defined the field as a structured social locus with its own rules where diverse agents engaged in a regulated struggle to transform the field according to their own interests. Usually what is at stake in this struggle is the acquisition of various types of cultural capital (Bourdieu, 1985):

“Capital, which may exist in objectified form – in the form of material properties – or, in the case of cultural capital, in the embodied state, and which may be legally guaranteed, represents a power over the field (at a given moment) and, more precisely, over the accumulated product of past labour (in particular over the set of instruments of production) and thereby over the mechanisms tending to ensure the production of a particular category of goods and so over a set of incomes and profits” (Bourdieu, 1985, p. 724)

Nevertheless, the concept of the Bourdieuan field can be useful for the examination of any social phenomenon if and only if the behaviour of the agents in the field is heavily determined by the structure and the characteristics of that field. This is why Bourdieu (1980) relegated the importance of autonomous reflexive behaviour and instead regarded as ontologically basal human practical behaviour which occurred only after the internalisation on behalf of the human agent of external structures and the emergence of specific dispositions in the human body and mind.

Hence, there must be a concept that summarises the way that

external structures can be internalised and this concept is the habitus. It is the intrinsic way that the logic of practice works, the capability of humans to internalise the external structures with which they interact in their environment, without being obliged to use their rational thought. Hence, it is a ‘structured structure that functions as a structuring structure’, or, to use Bourdieu’s exact words:

“The conditionings associated with a particular class of conditions of existence produce habitus, systems of durable, transposable dispositions, structured structures predisposed to function as structuring structures, that is, as principles which generate and organize practices and representations that can be objectively adapted to their outcomes without presupposing a conscious aiming at ends or an express mastery of the operations necessary in order to attain them.” (Bourdieu, 1980, p. 53)

The habitus is a concept that does not narrow down the states of consciousness that social scientists can examine to the products of human reflexive thought. Instead, Bourdieu (1980) insisted that practical knowledge that is accumulated in the human agent at the level of the unconscious is of paramount importance. And exactly because he moved beyond a restrictive understanding of human behaviour, which dealt only with human behaviour when humans thought, thanks to the juxtaposition of the concepts of the habitus and the field, he managed to explain the sociality of various entities—previously thought to be included in the realm of the inapproachable and incomprehensible by sociology—

idiosyncrasies of human behaviour such as taste and art perception (Prior, 2005).

To describe the place of technological entities within this theorisation, Sterne (2003) argued that technology formed part of the practices of the agents of the field:

“Because technologies do not have an existence independent of social practice, they cannot be studied in isolation from society or from one another. They are embodied in lived practice through habitus, and so even the most basic ‘phenomenological’ aspects of technological practice and experience are themselves parts of the habitus. Their nature (or artificiality, as the case may be) is second nature. At the level of actual practice, technologies are always organized through (and as) techniques of the body; and so the ‘form’, ‘use’ and ‘function’ of a technology cannot be separated from the practices with which it is bundled. As part of the habitus, technologies and their techniques become ways of experiencing and negotiating fields. Technologies are always implicated in and shaped by social struggles.”
(Sterne, 2003, p.385)

Technological entities are elements of the practices each agent develops within the field. Human interactions with them are embodied via the habitus and they are the outcome of the regulated struggle that takes place within the field.

In fact, technological entities are so intricately linked with the habitus that they can be considered part of it:

“As I will argue, technologies are essentially subsets of habitus – they are organized forms of movement. In this way, technologies are theoretically unexceptional. They are very similar to other ways in which we organize social practice through the habitus. This alternative to approaches that exceptionalize technology allows us to do away with the yawning gap between 'technology' and 'society' that has animated so many theories of technology” (Sterne, 2003, p. 370)

The most interesting characteristic of these definitions is that they contain many of the necessary elements of an innovative understanding of technological change. The field is a domain that is structured and hierarchical. Hence, using this concept, it is possible to provide insight regarding the existence and interactions of humans within bureaucratic institutions, such as universities (e.g. see Bourdieu, 1984; 2001). It is a place where there are dominated and dominating agents, i.e. a place where humans are subject to various types of control. The social phenomena observed within the field, including the types of craft that the technologists might develop depend on the struggle between the agents who are active in the field. It is this regulated struggle that determines the rationale of technological development within a field. This struggle however, is not strictly economic or cultural since the types of capital over which the agents compete are cultural as well as economic. Therefore, the greatest contribution of the concept of cultural capital is that it helps to avoid reductive explanations (economism or culturalism) of the craft aspect of technological innovation which is determined by

the field as a whole. At the same time however, it is possible to examine class struggle and market competition either as part of the competition for power within the field or as external forces that influence it.

Furthermore, the concept of the field facilitates the move from the macroscopic to the local level and vice-versa. Bourdieu (1997, 2001) used the metaphor of the field exactly because it was a strictly differentiated type of domain. Each position within the field has its own characteristics and not all the rules that apply to one agent within the field apply to all of them. It is exactly due to these differences that it makes sense to talk about strategies and evolution of the field. Moreover, fields are suitable for the study of modern institutions since Bourdieu defined the field as a feature of modernity (Bourdieu and Wacquant, 1992), an example of its specialisation effects, and argued that it was a characteristic of modernity to generate more and more diverse fields, such as, for example, the field of televised journalism (Bourdieu, 1996). In fact, Bourdieuan fields can be further separated into subfields whenever a qualitatively different type of resource emerges (Bourdieu and Wacquant, 1992) and this is extremely useful to my analysis because it aims to articulate what happens within a technological sector when a technological innovation emerges.

All in all, using the field, I will be able to analyse agents of diverse and distinct institutions who share the goal of developing new

types of technology and hence compete for various types of capital, which require definition. I will do so without any preconceptions about their behaviour, as those I would have to accept for example if I analysed the production of new technology as a constructed market full of utility maximizing agents. In addition Sterne's (2003) analysis of the implications of the Bourdieuan approach for technology points to the direction of the 'blurring' of a naïve separation of society and nature, something that is among the necessary elements for a new understanding of technological innovation, as has also been argued by ANT (Latour, 1991). Finally, the field allows for a better examination of the relations between the field and the rest of socio-technical reality than the concept of the autonomous complex system (for example, Luhmann, 1984), which in the case of technology might be crucial for its development.

The problem is that no matter how useful the field might be, the habitus is a concept with significant shortcomings. The reason is that the habitus does not allow enough space for the more reflexive and innovating aspects of human behaviour, because agents are 'slaves' to internalisations of pre-existing structures and cannot negate the dispositions which result from the latter (Jenkins, 1982), and eventually reproduce them. Hence, it is very difficult to understand how humans could induce change voluntarily. Bourdieu (2001) allowed for one possibility of reflexive human behaviour, i.e. when the dispositions of

the agents were structured by external structures that no longer existed and instead, had been replaced by new structures. However, if that is the case, then it is necessary to argue that the source of change within human society is not humans themselves but either pure luck or unexpected changes of the field, unrelated to the behaviour of the agents, something that could be argued to be a reductive explanation.

Following such a rationale, De Certeau (1990) argued that considering the characteristics of human societies as given and denying any effort to provide them with a sociological explanation, was something that proved to be unsatisfactory not only to sociology but to ethnology as well. His student, Hennion (Looseley, 2006) whilst commenting upon the development of tastes, advanced this idea even further by arguing that Bourdieu's theorisation ultimately leads to the conclusion that it is social structure that determines the way agents within the fields interact with artistic objects (Hennion, 2007), thus undermining Bourdieu's effort to overcome the frontiers between subjectivism and objectivism (Bourdieu and Wacquant, 1992). Hennion argued that researchers could observe moments when human agents interacted reflexively with their objects of interest, e.g. when agents try to obtain as much satisfaction as possible from the consumption of a good wine. He proposed to replace the habitus and the Bourdieuan approach with the idea that the interactions (such as taste) of agents with

things are co-determined by both the reflexive yet socialised agents and the things themselves:

“The key question is definitely to do with the problematic presence of ‘the object’ within taste. What place is accorded or not accorded to the responses of objects, that is, to their ‘respondance’? For being ‘socially constructed’, the object exists nonetheless: it is, on the contrary, more present. We cannot continue to oscillate indefinitely between linear interpretations, that is, ‘natural’ ones – taste comes from things themselves – and circular interpretations, that is, ‘cultural’ ones – objects are what we make them – in this strange zero sum equation between objects and society. By showing how taste comes to things thanks to the *amateurs*, we fully rejoin pragmatism. Pragmatism made us give up the dual world – things on one side autonomous but inert, things on the other side, pure social signs – so as to enter a world of mediations and effects, in which the body that tastes and the taste of the object, the group that loves it and the range of things they love, are produced together, one by the other. The attachments link all of these heterogeneous elements, at once determinant and determined, that carry constraints and make the course of things rebound.”
(Hennion, 2007, pp. 111-112)

Hennion introduced to the critique of the habitus the need to consider that the reflexive thinking of the agents might be more ontologically essential than Bourdieu (1980) admits.

These weaknesses of Bourdieu’s theorisation led Mouzelis (2008) to argue that he underestimated three possibilities of human reflexive action:

- Reflexive action that occurs when there are

inconsistencies between dispositional structures and interactive structures, i.e. structures that occur at the moment of action and could not have been already turned into dispositions.

- Reflexive action that occurs when there are contradictions within an agent's habitus, i.e. when the external structures that are being internalised include contradictory elements which induce practices which contrast each other.

- Reflexive action that occurs totally independently of an agent's dispositions.

If all these possibilities for reflexive action are accepted, then the habitus is inadequate as a concept, since it does not provide any understanding of various aspects of human behaviour. Perhaps, then, it should be completely abandoned.

The problem with this option is that firstly, it would not be very easy to ignore Bourdieu's (1980) critique of objectivist and subjectivist approaches and secondly, it would be premature to just throw away the very helpful tool of the field, especially in cases like my research on the sector of marine energy technology in which the concept of the field seems promising. Nevertheless, if not abandoned, the Bourdieuan approach has to be rectified, and especially the habitus. If there is a relationship between the practices of human agents and the social structures in and through which they exercise these practices, this

relationship is not mediated by the Bourdieuan habitus. If that is the case, I have to find other aspects of the Bourdieuan approach that could serve as the basis for the understanding of human social behaviour.

Two authors proposed alternative ways to use Bourdieu's theorisation. King (2000) rejected the habitus for the same reasons that Mouzelis (2008) rejected it as well. However, he argued that there was still value in Bourdieu's theory. To be more precise he claimed that beyond the habitus there was a Bourdieuan practical theory capable of transcending the frontier between objectivism and subjectivism which could be useful for research which attempts to understand the behaviour of agents who interact in a field's institutions. As he put it (2000, pp. 421-422):

“...Bourdieu undermines the notion of objective, determining social rules and social structure which are prior to individuals who are isolated from their social relations with other individuals and placed before these rules or structure. In place of these objective rules or structures which are imposed upon isolated individuals, Bourdieu's “practical theory” highlights the mutual negotiation of social relations between individuals. Social life does not consist of a synchronic map or system which imposes itself upon the individual but only of practical and negotiated interactions between individuals. By replacing structure and agency with interacting, social individuals, Bourdieu has overcome many of the dualisms of conventional social theory. On this “practical theory,” there is no longer the individual and society, the subject and the object, but only individuals interacting with other individuals.”

King explained that this theory was incomplete and that Bourdieu was unfaithful to his own aspirations as soon as he chose to make the concept of the habitus the primary determining factor of the agents' practices. Even so, the hint about the importance of 'the mutual negotiation of social relations between individuals' could be used as the starting point for a theory that would be able to incorporate reflexive human behaviour and practical behaviour based on dispositions. A negotiation always involves a limited amount of rational reflexive calculation, whereas, the other negotiators would function as enabling and constraining entities if one would want the communication and subsequent negotiation to succeed.

Following a totally different rationale, Rogers Brubaker (1993) suggested that it would be possible to envisage reflexive theoretical thinking as just one of the dispositions that specific types of habitus have structured in the minds of specific types of agents (1993, p.216):

“Reflexivity can and should be incorporated in the habitus, in the form of a disposition to monitor its own productions and to grasp its own principles of production.”

It might seem that this suggestion has rescued the concept of the habitus by arguing that reflexive thinking is simply a part of a type of habitus. However, appearances can deceive. Firstly, because even if reflexivity is

part of a habitus, it is also something that negates it: reflexive thinking means that the structured structure does not function as a structuring structure. In the moment of reflexive thinking, the agent has the capacity to evaluate the structures in and via which he or she thinks. Secondly, even under the assumption that this is not a problem, it would be very difficult to explain the reasons why, if human agents have the capacity to evaluate these structures and to choose strategies in a less determined way, this reflexivity appears only in specific cases determined by the habitus. Nevertheless, Brubaker pointed in the right direction: the objective is to find a way to understand the balance between the practical habitual behaviour and reflexive behaviour. Only once I do that, does it become possible to keep the good parts of Bourdieuan analysis and avoid the problems the habitus imposes.

3.2 Castoriadis

The Bourdieuan approach, due to the habitus, understands the human agent as an entity that is inexorably determined by the structure of the field (Jenkins, 1992). This deficiency means that his approach is unable to understand technological innovations as change: the Bourdieuan field's structure does not change due to the actions of the agents therein. And the inability to understand change means that

Bourdieu was unable to understand the roots of performativity of both human agents and non-human entities alike. One of the most thought provoking theorisations capable of addressing this issue is Castoriadis' (1975) anti-structuralist approach (Joas et al., 2009), which is described in the following sections.

3.2.1 Castoriadis' Theorisation

Castoriadis argued that modern occidental philosophy, due to its Christian and Platonic (Castoriadis, 2004) foundations, followed what he called *ensemblist-identitary (ensidic)* logic, based its ontology on rationality and determination (Klooger, 2014A) and thus, promoted a determined essence of, firstly, sociotechnical reality as a whole:

“The inherited logic-ontology is solidly anchored in the very institution of social-historical life;... Its core is the identitary or ensemblist logic, and it is this logic that rules sovereignly and ineluctably over the two institutions without which no social life can exist: the institution of the *legein*, the ineffaceable component of language and of social representation, and the institution of *teukhein*, the ineffaceable component of social doing... For identitary logic is the logic of determination, which particularizes itself, depending on the case, as a cause and effect relation, as means and end or as the logic of implication.” (Castoriadis, 1975, p. 175)

And secondly of the human agent:

“In modern times, there remains, no doubt as the heritage of Christianity and of Platonism, the idea of an individual-substance, itself ontologically autarchic and self-producing, that enters into a social contract (a notional one, certainly; transcendental, if one prefers) whereby this substantive individual would make an agreement with others to found a society or a State (but should not we ask whether the individual might be incapable of doing this, even notionally or transcendently?). Whence the ideas of the individual against the State or against society, and of civil society against the State.” (Castoriadis, 1996A, p. 95)

In these two quotes, Castoriadis suggested that both socio-technical reality with its most basal institutions, i.e. *legein* (language and the ability to communicate and create meaning) and *teukhein* (the ability to construct a world of innovative material objects) as well as the human subject were envisaged by modern philosophy not as creations but as deterministic derivations of specific ‘laws’, even if this law was the principle of the autarchic and ‘independent’ individual. Castoriadis (1975) claimed that such theorisations were unable to understand the qualitative characteristics that distinguish socio-technical reality before and after the occurrence of a change. If everything is determined, then there is no real creation and every human lives in a world which is essentially static.

Castoriadis did not negate the existence of ensidic aspects within sociotechnical reality. He clearly argued that certain dimensions of this

world had to be ensidic, otherwise life and society would not exist:

“We thus remark that all effective institutions of society, and all those we might imagine as effective and viable, necessarily include an ensemblistic-identitary (ensidic) dimension and that the latter has a certain grasp upon the world, sufficient as to need/usage, otherwise these societies could not exist. How is the world tout court, then, since the ensidic dimension has, roughly speaking and to a large degree, a grasp upon it?

The response is: The world tout court includes within itself a dimension that not only lends itself to an ensidic organization but corresponds to such an organization.”
(Castoriadis, 1989A, p. 364)

Here, Castoriadis suggested that the world does contain an ensidic dimension and that this dimension is susceptible to organization by humans. Had it been otherwise, the existence of society would not have been possible. To create society and the lesser institutions which comprise it, humans *have to be able* to differentiate, organise and combine elements of this world.

However, Castoriadis’ argument was that the world does not include *only* the ensidic dimension. The world, including socio-technical reality, includes indeterminacy and chaos. Hence, it should be described as a magma:

“The world indefinitely lends itself to ensidic organizations. The world cannot be exhausted via these organizations. These two statements define a mode of being, which I have called the mode of being of the magma (MSPI, IIS, LMQA [1983]) and which we rediscover everywhere (save in mathematical

constructions separated from their foundations).”
(Castoriadis, 1989A, p. 364)

In this quote, Castoriadis used the magma as a metaphor which described the world as an entity which contained an ensidic dimension and something else. This ‘something’ is the indeterminacy that can be found at the very foundations of socio-technical reality. The coexistence of the ensidic and the indeterminate dimensions of socio-technical reality can be adequately represented by the magma which is an entity that can take many different forms which constantly change, but at the same time these forms cannot be predetermined.

In a magmatic socio-technical reality, there is no place for determinism. Instead, there exists “true” creation, i.e. creation which is not prefigured by the past conditions of socio-technical reality. Castoriadis called this type of creation, creation ex-nihilo in order to highlight the fact that it emerges out of nothing, as can be seen in the following quote:

“Castoriadis’s interpretation of creation ex nihilo rests ultimately on the distinction between (mere) difference and (radical) otherness. For Castoriadis difference is tantamount to the production of the same within what is already given both on the level of ‘extant’ being and on the level of meaning. Otherness points to the emergence of unprecedented modes of being(s), which cannot be traced back – or explained with regard to – to pre-established nexuses of relations, meanings, etc. The social-historical is then seen as the field of the creation of otherness, since

history is 'precisely our authentic otherness, other human possibilities in their absolute singularity' (p. 163). (Mouzakitis, 2014A, pp. 53-54)

Here, Mouzakitis explained that Castoriadis' concept of creation included the possibility of the emergence of entirely new forms, i.e. forms which cannot be derived from previously existing socio-technical reality. These forms, these *eide* are entirely qualitatively distinct from previously existing socio-technical reality and cannot be derived in any sense from the latter. Moreover, it is primarily socio-technical reality and not in general the world or nature the locus where this emergence takes place.

Within this context, Castoriadis (1975) argued that the ontological understanding of time should change to understand human history. Time should not be understood as something equivalent to space, i.e. something that involves only transformations of entities which are essentially the same. Castoriadis (1975) concluded that time includes changes and emergence of new forms which could neither be entirely reduced to the past nor derived as a whole from previous conditions:

“Time as the 'dimension' of the radical imaginary (hence, as a dimension of the radical imagination of the subject as subject as well as of the social-historical imaginary) is the emergence of other figures (and, in particular, of 'images' for the subject, of social-historical *eide*, imaginary social institutions and meanings for society). It is the otherness-alteration of figures and, originally and in its core, it is

this alone. -- These figures are other not depending on what they are not (their 'place' in time) but depending on what they are; they are other inasmuch as they shatter determinacy, inasmuch as they cannot themselves be determined, to the extent that they are determined, on the basis of determinations that are 'external' to them or that come from somewhere else.” (Castoriadis, 1975, p. 193)

Here, Castoriadis explained that within socio-technical reality there are entities which emerged as time passes without being determined by what already existed within this socio-technical reality. This is the reason why time cannot be considered as something equivalent to space. It is impossible to travel through time even theoretically, exactly because Castoriadis understands time as the possibility of the appearance of something entirely new. These ‘new’ entities (which could be ideas, figures or representations) include an aspect that is created ex-nihilo and it is this aspect that defines how agents perceive them as real and how they interact with them rationally.

However, at this point Castoriadis’ readers should be very cautious. The following quote highlights the fact that, if change *is not determined* by past conditions of socio-technical reality, this does not mean that change *is not related* to past conditions of socio-technical reality:

“...it is clear that social-historical creation (as well as, moreover, creation in any other domain), if it is unmotivated - ex nihilo - always takes place under

constraints (it does not occur in *nihilo* or *cum nihilo*). Neither in the social-historical domain nor anywhere else does creation - signify that just anything can happen just anywhere, just any time and just anyhow.” (Castoriadis, 1989A, p. 370)

In this quote Castoriadis clarified that the unmotivated change he described, was not a change that was unrelated to and unconstrained by the pre-existing conditions of socio-technical reality. On the contrary, the fact that change does not occur in *nihilo* or *cum nihilo*, means that it has to happen within previously existing conditions and that it has to coexist and “use” specific aspects of these conditions in order to happen.

If change takes place primarily within socio-technical reality and ‘needs’ to relate to aspects of this reality, than what remains to be explained is the ‘source’ of this change. Castoriadis claimed that, within human history, this source is the human psyche and, in particular the fact that it contains a radical imagination. Castoriadis (1994, p.331) argued, by paraphrasing Hegel, that humans were mad animals with a radically distinct type of psyche. Human psychic reality is characterised by the defunctionalisation of the psyche in relation to biological processes, the domination of representational pleasure over organ pleasure, and the autonomisation of the imagination the affect and the desire (Castoriadis, 1989B, pp. 386-389).

A defunctionalised psyche is a psyche the representations of which are not determined by the needs of the body’s survival (which is

what happens to animals). On the contrary, the defunctionalised psyche offers humans the opportunity to create their own image of the world and to posit themselves as subjects within it. Humans can choose what they perceive, love/hate and intend to an extent greater than any other animal. And the most important instrument which humans use in order to create all kinds of different perceptions and images is, according to Castoriadis, their *radical imagination* which is the most distinctive component of the human psyche:

“Presupposed by these two traits, but not identical to them, is a third which is undoubtedly the one that characterizes the human psyche **par excellence**: the **autonomization of the imagination**. We are speaking here, of course, of the radical imagination which is not the capacity to have “images” (or to be seen) in a “mirror” but the capacity to posit that which is not, to see in something that which is not there... For the human psychism, there is unlimited and uncontrollable [**immaîtrisable**] representational flux, a representational spontaneity that is not subjected to an ascribable end, a rupture of the rigid correspondence between image and X or a break in the fixed succession of images.” (Castoriadis, 1989B, p. 387)

In the quote above, Castoriadis explained that the, observed in animals, simple and rigid correspondence between an object and its perception, was replaced by a representational flux of infinite possibilities, even the possibilities of, firstly, imagining something that does not exist and secondly of creating symbols, as can be seen in the following quote:

“The radical imagination is also at the root of another extraordinary ability of human beings: the ability to symbolize. It is thanks to the radical imagination that human beings are able to see a thing in another thing. That is what *quid pro quo* is: taking one thing for another; seeing the word dog in writing and having it represent a dog, having a dog become present for me. As opposed to the animal level, at which there are only signals—the smell of a predator, for instance—attached to an object, for human beings, there are not only signals; there are, above all, symbols. And that is what makes language possible. It is the fact on which language rests.” (Castoriadis, 1996B, p. 205)

Here, Castoriadis made clear that the emergence of things that are not present and the creation of symbols, i.e. the creation of entities which correspond to other elements of socio-technical reality and represent them when one human interacts with others, is exactly the emergence of “otherness”. The creation of otherness is the emergence of entities which are not determined by previously existing socio-technical reality and this is exactly what these creations of the radical imagination are. After all, the creation of symbols and undetermined images in general cannot be understood as a product of biological necessity. This emergence is the key characteristic of Castoriadis’ ontology which I presented in the previous paragraphs. This is the source of *ex-nihilo* creation within socio-technical reality and this is the reason why human society is, *par excellence*, the locus where one can observe *ex-nihilo* creation.

Castoriadis (1975) was adamant that the part of the human psyche with the capacity to induce *ex-nihilo* creation (i.e. *radical imagination*)

should be strictly separated from previous definitions of the terms imagination or imaginary as can be seen in the following quote (Castoriadis, 1975, p. 3):

“The imaginary does not come from the image in the mirror or from the gaze of the other. Instead, the 'mirror' itself and its possibility, and the other as mirror, are the works of the imaginary, which is creation ex nihilo. Those who speak of 'imaginary', understanding by this the 'specular', the reflection of the 'fictive', do no more than repeat, usually without realizing it, the affirmation which has for all time chained them to the underground of the famous cave: it is necessary that this world be an image of something. The imaginary of which I am speaking is not an image of. It is the unceasing and essentially undetermined (socialhistorical and psychical) creation of figures/forms/images, on the basis of which alone there can ever be a question of 'something'. What we call 'reality' and 'rationality' are its works.”

Here, Castoriadis explained that the “otherness” which emerges from the function of the radical imagination has nothing to do with fiction, phantasies and any other “unreal” creations. On the contrary the images created by the radical imagination are a prerequisite for the existence of both rationality and reality. Humans would not be able to distinguish what is rational and real if they weren’t able to create images of aspects of socio-technical reality and distinguish between them. Hence, the reality and rationality perceived by each human is a creation of her or his radical imagination.

Castoriadis (1975) did not argue that the radical imagination

functioned in void and it is really important to remember his conclusion that change could emerge ex-nihilo but not in nihilo or cum nihilo. Hence, in his theorisation, the radical imagination formed part of an ontology (Adams, 2011) which was based on two more elements called the first natural stratum and the social imaginary:

“The institution of society by instituting society leans on the first natural stratum of the given and is always found (down to an unfathomable point of origin) in a relation of reception/alteration with what had already been instituted.”
(Castoriadis, 1975, p. 369)

In fact, the activity of the psyche takes place within a socio-technical reality already ‘colonised’ by multiple entities. Some of these entities are natural whereas others are created and shaped by humans. In addition human agents and non-human entities are involved in already instituted processes which generate results, predictable or not (Castoriadis, 1975). The radical imagination has to function within the confines of a world where nature and society cannot be ignored, because they provide the elements used by the radical imagination in order to create ex-nihilo. It is important to clarify the relation between these elements and the radical imagination.

Nature was defined by Castoriadis (1975) as the first natural stratum upon which humans constructed, what he called social imaginary, i.e. what is usually referred to as society and culture

(Castoriadis, 1975). To describe the relation between society and nature, Castoriadis used the Freudian term *Anlehnung*, as can be seen in the following quote:

We discussed at length above the relation of society to what I termed the first natural stratum, a relation designated by the Freudian term 'leaning on' (*Anlehnung*). Society's doing and representing/saying are neither dictated by an indubitable, in-itself, being-thus of the natural stratum nor are they 'absolutely free' in relation to the latter -- this is self evident... The world of significations instituted in each case by society is obviously neither a copy or a tracing ('reflection') of a 'real' world, nor is it without any relation to a certain being-thus of nature... The organization of this world leans on certain aspects of the first natural stratum, where it finds points of support, incitements, inductions. However, not only is it never purely and simply the repetition or reproduction of this stratum; it cannot even be described as a partial and selecting 'sampling' of it. What is 'sampled' is so only in relation to and on the basis of an organization of the world posited by society; (Castoriadis, 1975, p. 347)

The quote above revealed that Castoriadis envisaged the relation between nature and society as a relation of support or as a provision of opportunities and constraints and certainly not as a deterministic relation of causation. Nature provides elements and conditions which have to be taken into account by humans (such as, for example, the existence of the two sexes), but the way humans understand and react to them, using their radical imagination, is something determined at the level of what Castoriadis (1975) called the social-historical and not at the level of the

first natural stratum.

The fact that human behaviour and understanding of natural entities is determined at the level of the social-historical and only leans on the first natural stratum, reveals another important aspect of Castoriadis' theorization, i.e. his view that reality was ontologically stratified, as can be seen in the following comment of Klooger (2014B, p. 131):

“Castoriadis regards the universe as ontologically stratified, with different strata corresponding to different modes of being with their own laws and their own types of law – that is, not only different laws, but other meanings of ‘law’ and ‘lawfulness’. The laws of one stratum do not rule beyond that stratum, and thus do not determine the phenomena within other strata. So, purely physical laws do not determine biological phenomena, biological laws do not determine psychical phenomena, and psychical laws do not determine social-historical phenomena.”

Here, Klooger described an ontologically stratified world that was used by Castoriadis to avoid theorising a world dominated by deterministic causation. Only if different strata of ‘outhereness’ (as a theorist of ANT would call the world) possess and create their own meanings of ‘law’, would it be possible to theorise a socio-technical reality which simply leans on nature and is not determined by it. Moreover, it is only if an ontological stratum can create its own laws that true creation can have a meaningful impact on history. To give an example, if a researcher

adheres to geographical determinism, it is very difficult for her or him to understand the importance of human creativity in human history, the importance of radical imagination.

If the first natural stratum ‘supports’ the function of the radical imagination, the social imaginary is composed by the function of myriads of radical imaginations who lean on the first natural stratum and who interact and use everything that was created by humans in the past. Hence, the social imaginary is not a stable and unchanged background of human action, but rather a force which firstly creates its own laws, meanings and significations and secondly is creative and magmatic in form (Castoriadis, 1975).

Hence, the social imaginary constitutes the force that institutes what humans recognise as socio-technical reality, or as Castoriadis would put it, the social-historical:

“The social-historical institution is that in and through which the social imaginary manifests itself and brings itself into being. This institution is the institution of a magma of significations, imaginary social significations. The participable representative support of these significations -- to which, of course, they are not reducible and which can be direct or indirect -- consists of images or figures, in the broadest sense of the term: phonemes, words, bank currency, jinns, statues, churches, tools, uniforms, body paintings, numerical figures, border posts, centaurs, cassocks, lictors, musical scores -- but also the totality of what is perceived in nature, that is or could be named by the society in question.” (Castoriadis, 1975, p. 231)

In the extract above, Castoriadis argued that the social imaginary brings itself into being through the creation of institutions. And the institution which encompasses all others is the institution of the social-historical in its entirety, which can be described as the self-deployment of society in time (Mouzakitis, 2014B). The social-historical can be described as the place where one can observe the radical imaginary, i.e. ex-nihilo creation as it manifests itself within the ever-changing socio-technical reality. Within the social-historical one can encounter many other lesser institutions such as the human language, art, science, technology and political and economical institutions.

However, what is really important in Castoriadis' analysis is the fact that, the creation of institutions by the radical imagination consists of a simultaneous creation of significations i.e. of forms of meaning. Castoriadis has created a 'grand theory' that does not consist of eternal historical laws, but that, instead, investigates the way meaning is created through human radical imagination. And, since each society that has existed so far differs from others, then that means that the significations which are created in each society, differ more or less to the significations which emerge in other societies. The main reason why this phenomenon exists, is that in each society there are some predominant instituted forms of meaning that influence all other institutions. Castoriadis called these forms of meaning, 'social imaginary significations', and they are the

ones that render a human into a citizen of a late modern country or a hunter of a hunter-gatherer tribe. Castoriadis claimed that it was much more difficult to change these features because they were so deeply ingrained within each society that affected tremendously the way humans thought and, in a sense, constituted it:

“We are to think of the world of social significations as the primary, inaugural, irreducible positing of the social-historical and of the social imaginary as it manifests itself in each case in a given society; a positing which is presentified and figured in and through the institution, as the institution of the world and of society itself. It is this institution of significations -- always instrumented in the institutions of *legein* and *teukhein* -- which, for each society, posits what is and what is not, what has worth and what does not, and how, in what way is or is not, does or does not have worth that which can actually be or have worth.” (Castoriadis, 1975, p. 368)

To give an example of how they function, Castoriadis mentioned the legend of a group of slaves living in an ancient city who successfully revolted against their masters and managed to escape and build their own city. The structural characteristics of their society where they had grown up however, forced them to ultimately apply to their new city the only economic system that they had ever experienced: slavery (Castoriadis, 2004). Nevertheless, social imaginary significations can change either unintentionally via historical processes or intentionally if groups or individuals understand that they can be doubted and negotiated and if

they understand that a society can seek autonomy and choose in a democratic way its type of governance (Castoriadis, 2008).

To conclude this presentation of Castoriadis' analysis of the social imaginary, it is important to take into account two points. Firstly, the social imaginary has a magmatic form (and, hence, changes in a non-deterministic way) because it is created through the function of the radical imagination of humans. Secondly, the social imaginary is to a large extent formed in accordance with the social imaginary significations which are predominant in each society. Castoriadis concluded that, within this framework, the question of the relation between the individual and society was wrong:

“The centrality of the psyche is nowhere clearer than in Castoriadis’s observation that the question which has long driven sociology – the question of the ‘relationship between the individual and society’ – is the wrong question. The focus, he argues, should instead be on the relationship between the psyche and society, for these are the two irreducible poles of the relationship. The individual, in contrast, is the always already socialized psyche (Castoriadis, 1987, pp. 102– 107; 1997a, p. 134) and, as such, is in a very real sense a social-historical institution – an artefact of society, so to speak.” (Smith, 2014, p. 75)

If, as Smith argued, the individual is an artefact of society, i.e. an artefact of social imaginary significations, then the real contrast is between the institutions which are born according to the dictates of these social

imaginary significations and the psyche whose radical imagination is the locus from which true creation emerges. The investigation of every socio-technical phenomenon requires the investigation of the relation between the function of the psyche of the humans involved and the society in which they are found, as they lean on the first natural stratum.

3.2.2 *Castoriadis and Technology*

Castoriadis' theorisation provided researchers with the necessary tools to understand change. Replacing the contrast between individual and society with the contrast between psyche and society allowed for the development of an approach that represented a break with the ensemblist-identitary modernist understanding by appreciating change and real creation. In fact, in his essay 'Technique', technological change was described as an arbitrary and absolute creation, i.e. creation that occurred *ex-nihilo*, but not *in-nihilo* or *cum-nihilo*:

“What technique brings into being is not, in the crucial instances, an imitation or reworking of a natural model (even though a vague analogy may by accident be found in nature); it is something which, in relation to nature, is ‘arbitrary’... To create a technical object is not to alter the present state of nature, something accomplished as well by moving one’s hand; it is to constitute a universal type, to posit an *eidos* which henceforth ‘is’ independently of empirical exemplars.” (Castoriadis, 1978, p.239)

In this extract, Castoriadis, emphasised the fact that technological entities and their invention are true creations and not simple imitations or derivations of natural entities. These true creations originate in the incessant activity of the human psyche, i.e. to be more precise, the radical imagination and its interactions with the social imaginary and the first natural stratum.

However, instead of simply stating that techniques are a derivation of the contrast between psyche and society, Castoriadis argued that the radical imagination interacts with two distinct regions of what he called ‘brute reality’:

“...what makes possible not just technique, but making/doing of any kind, is the fact that brute reality is not fixed, but bears within it immense interstices which allow of movement, assembling, alteration, division;... Technique thus brings about a division of the world into these two regions fundamental to human making/doing: the region which resists in every way, and the region which (at a given historical stage) resists only in a certain way. It constitutes, within brute reality, that in relation to which nothing can be done, and that in relation to which some kind of making/doing is possible. Technique is creation in that it makes arbitrary use simultaneously of the rational make-up of the world and of its indeterminate interstices.”
(Castoriadis, 1978, p.240)

Here, ‘brute reality’ was described by Castoriadis as an entity that is composed of the region which is beyond any kind of human interference

on the one hand, and the region which is malleable in the hands and minds of humans. The technique that exists in this world emerged exactly because humans interact with the latter region and act under the constraints imposed by the former. To address the issue of technology, Castoriadis added another division of reality in two regions, other than the division between first natural stratum and social imaginary.

The existence of these two regions and especially of the region which is beyond human influence was the reason why Castoriadis rejected both technological determinism and social determination of technology:

“Every society creates its world, internal and external, and of this creation technique is neither an instrument nor a cause; it is a dimension, or, to use an apter topological metaphor, an everywhere dense sub-set. For it is present at every point at which society constitutes what is, for it, the real-rational.” (Castoriadis, 1978, p. 244)

In the quote above, Castoriadis depicted technology as a dimension of the social-historical. Since technology forms an integral part of any social formation and institution, it would be rather incorrect to describe it as an entity that is either a cause or an instrument of social phenomena. On the contrary, technology should be regarded as one more entity within socio-technical reality the evolution of which is determined by the interaction between psyche and society. And, due to the fact that the

interaction between psyche and society and the activity of the radical imagination is what constitutes what people consider real and rational, technology and its evolution take part in this constitution of the real, as an aspect or dimension of the social-historical.

The participation of the radical imagination in the constitution of reality and rationality was the main reason why Castoriadis made a distinction between technique and technology, as can be seen in the following quote by Curtis (2002, p.180):

“But the relevant issue here refers directly back to *CSII*'s distinction between *technique* and *technology*: technology is the societal choice—among a “ a ‘spectrum’ of techniques available at a given point in time”—of a given group (or ‘band’) of processes, for example, capitalist technology's selection of techniques that seek to *exclude* workers from the management of their own work so as to “fit in with capitalism's basic need to deal with labor power as a measurable, supervisable and interchangeable commodity” (p.104)”.

Using Castoriadis' own words, Curtis, in the extract above, explained that the difference between technique and technology was exactly the fact that the latter consists of the types of technique which correspond with a particular socio-technical reality. Technological change occurs within this constraint. Hence, it would be inconceivable, within a capitalist institution, to promote a technological innovation that increases the workers' control over their own work. Such an innovation

negates the social imaginary significations of a modern capitalist society.

And these social imaginary significations are extremely influential. All technological innovations which take place within a society bear the marks of the social imaginary significations which are predominant therein. In modern capitalist societies, there are two, extremely important for the issue of technological change, social imaginary significations, which Castoriadis described in the following extract:

“We must consider the emergence of the bourgeoisie, its expansion and final victory in parallel with the emergence, propagation, and final victory of a new “idea,” the idea that the unlimited growth of production and of the productive forces is *in fact* the central objective of human existence. This “idea” is what we call a *social imaginary signification*... On the other hand, the philosophers and scientists apply a new and specific twist to thought and knowledge; there are no limits to the powers and possibilities of Reason, and Reason *par excellence* is mathematics... The marriage—probably incestuous—of these two currents gives birth, in diverse ways, to the modern world.” (Castoriadis, 1976, p. 184)

Here, Castoriadis described modernity as the society dominated by two similar ideas, i.e. the necessity to continuously expand production and the continuous expansion of the power of Reason. A society can be called modern if it considers rational to constantly increase its production of any kinds of goods via the application of the laws of a particular type of Reason, i.e. a reason which is akin to mathematics, to

more and more socioeconomic sectors. People in such a society find it very difficult to acknowledge the fact that there might be limits either in the amount of goods a society ought to produce or in the domains in which mathematical reasoning might be the most apt way to understand them.

Certainly, technology in such a society is of paramount importance, since it is the socio-technical locus where these two types of expansion meet. There, scientific knowledge, which was born out of mathematical reasoning is put to use in order to expand the production of an immense amount of goods. And if that is the case, then it is natural to suppose that technological change within a modern society is characterised by these social imaginary significations. The impact of these significations upon technological change is described in the following quote:

“We do not try to do what “would be necessary” or what we judge “desirable.” More and more, we do what we can, we work on what is deemed doable in the approximate short term. To put it more pointedly: we go after what we think we can achieve technically, and then we see what “applications” we can invent... What is technically feasible will be done regardless.” (Castoriadis, 1987, p. 249)

Castoriadis in the extract above claimed that modern technologists do not question themselves whether or not they should proceed with a specific innovation. They only care if they can create a new technological entity

and not if they desire to do so, or if this innovation would be beneficial for the majority of the people in their society. This condition is the reason why there are sectors in which scientists and technologists become more and more specialised, i.e. they know more and more about less and less (Castoriadis, 1987).

The immediate consequence of this type of technological change, is that there is no way to check technological development and see whether or not it will benefit the people in the long run, as Castoriadis described in the following extract:

“And such is, for modern humanity, the question of the relationship it maintains between its knowledge and its power, or, more precisely, between the constantly growing potential of technoscience and the manifest powerlessness of contemporary human communities.

The word “relationship” here is already a bad choice. There is no relationship. This power is powerlessness in the face of the basics of contemporary technoscience...” (Castoriadis, 1987, p.244)

And of course, if human communities are unable to check technological change, they are also unable to stop the expansion of the social imaginary signification that defines it:

“What is at issue here is one of the core significations of the modern Western imaginary, the imaginary of “rational” mastery and of an artificialized rationality that has become not only impersonal (nonindividual) but also inhuman (“objective”).” (Castoriadis, 1987, p. 246)

Researchers can conclude from the extracts above that Castoriadis did not envisage technique and technological development as something neutral, i.e. as something that can be used in any way possible. On the contrary, technological development takes place in such a way that guarantees that societies will make specific use of their creations. They will use them in ways that guarantee the reproduction and expansion of the core social imaginary significations. In the case of modernity, technological change guarantees the expansion of rational capitalist mastery of society and nature, a conclusion that is similar to the—discussed in the previous chapter—conclusion reached by Weber (1905), when he described the iron cage.

However, unlike Weber, Castoriadis did not consider the continuous expansion of ‘capitalist rational mastery’ an inescapable fate of humanity. In the quote below, we can see that this is due to the fact that Castoriadis believed that there were also other, equally important, social imaginary significations in the modern Western world, beyond ‘capitalist rational mastery’:

“At the heart of the modern era, and ever since the end of the “Dark Ages,” two intrinsically antinomic but connected social imaginary significations have arisen. (We will not dwell on this connection here.) On the one hand, *autonomy* has animated the emancipatory and democratic movements which traverse the history of the West as well as the rebirth

of questioning and rational inquiry. The *unlimited expansion of "rational" mastery*, on the other hand, is at the basis of the institution of capitalism through its various phases (including, by a monstrous inversion: totalitarianism). It undoubtedly culminates in the unfurling of technoscience." (Castoriadis, 1987, p. 272)

Hence, there is a social imaginary signification in modern society that contrasts capitalist rational mastery. And this is the demand for autonomy and emancipation, as can be observed in the democratic movement which the West rediscovered after its disappearance with the demise of the ancient Greek culture. Thus, there is an escape from the iron cage and this escape can happen if people reflexively understand that they have to create their own laws for all the issues that concern them (Castoriadis, 2004). And the reason they can do that is their radical imagination: their capacity for real creation which is not determined by previously existing socio-technical reality.

Of course, the same applies to technology. Castoriadis made it very clear that humanity needs to understand and control the technological development of its society. However, he was also certain that, to achieve this goal, a massive change in the social imaginary significations of modern societies was necessary. This change would include among other things an 'attack on the division of labour in its hitherto known forms, and in particular on the separation between mental and manual work...' (Castoriadis, 1978, p. 257). Despite this piece of

information however, Castoriadis did not provide any more detail about the ways in which humans could change the ways they perceived technological change and about the steps needed to take in order to walk this road.

3.2.3 Castoriadis: Critique

The analysis in the previous section revealed that Castoriadis's theorisation and, to be more precise, his concept of radical imagination is the best possible starting point for a theory capable of understanding firstly technological innovation as true creation and secondly why specific innovations appear where they appear. This way it is possible to understand the craft aspects of technology and the reasoning which technological change follows in each society. However, there are some issues that need further clarifications.

Following Castoriadis (1975), the qualitative characteristics of innovations have to be related in one way or another to the pre-existing characteristics of the already instituted social reality which leans on the first natural stratum and creates socialised individuals. Without relating to this pre-existing social reality, innovations would not be successful. In fact, for a technological innovation to be successful, it is necessary to involve some aspects of the pre-existing social reality in its qualitative

characteristics. However, in each society, there are specific social imaginary significations which are predominant and have already shaped the 'brute reality' where technologists work.

If that is the case, then technological innovations have to bear the imprint of these social imaginary significations. Castoriadis (1978; 1987) acknowledged this fact, when he described how the social imaginary signification of capitalist rational mastery defined technological development in modernity. The problem is, however, that if technological innovations follow the reasoning of the predominant social imaginary significations, a specific socio-technical reality simply reproduces itself. Even though humans have radical imagination, the fact that they are shaped according to specific social imaginary significations, means that they can create only in determined ways.

This problematic point in Castoriadis' theorisation has been acknowledged in contemporary literature. One of the first researchers who criticised Castoriadis along those lines was Arnarson, whose critique originated in his evaluation of Castoriadis as a civilisational analyst, as can be seen in the following extract:

“But the retreat from specific issues, evident in the initial discussion of approaches to the social-historical, limits the impact of Castoriadis' innovations. The idea of imaginary significations as a defining feature of the social-historical does not lead to any sustained engagement with other theoretical projects, and there is no attempt to concretise it

through re-examination of particular themes or discursive domains... A general distinction between levels of institutionalisation thus overshadows the more specific differences between patterns of institution and signification that set whole cultural or civilisational complexes apart from each other; as a result, the potential significance of Castoriadis' rethinking of the imagination for a comparative analysis of civilisations does not become clear. (Arnarson, 1996, p.14-15)”

Here, Arnarson pointed out that Castoriadis tended to overemphasise the predominance of social imaginary significations and, in doing so, missed the importance of the idiosyncratic characteristics which might determine specific social, cultural and civilisational complexes. Understanding the similarities and differences found in specific civilisational complexes is a sine qua non of civilisational analysis. Without this, it is impossible, if one follows Castoriadis' point of view, to understand the way each civilisation, culture or society created itself to be similar or different to others. And, if Castoriadis' approach is unable to understand these differentiations, then it is also unable to understand the emergence of otherness which caused it.

Following the same reasoning, Klooger (2005) and Adams (2005), argued that Castoriadis' approach suffered from this defect because he insisted that creation is absolute and not contextual. Both authors claimed that there were points in Castoriadis' works where one could observe a tacit understanding of creation as interpretation. However, he rejected to acknowledge the benefits of theorising creation

as interpretation because he was afraid of re-introducing an ensidic logic in his work. However, the benefits of locating creation into a context can be substantial:

“In conclusion, Castoriadis neglects to incorporate three levels of interpretative activity in creation. First, interpretation itself includes a constitutive creative moment. Second, as underdetermined horizons of meaning, social imaginary significations, once created, themselves always already require further interpretation and elaboration, that is, the world still requires ongoing interpretation, its underdetermined nature allowing for a conflict of interpretations. Finally, the creation of the social-historical world occurs in the context of interpretation and transformation of already existing historical constellations of meaning. As such, it would seem more helpful to characterize creation as contextual rather than absolute.” (Adams, 2005, p. 35)

In this quote, Adams concluded, just as Arnarson (1996) that the importance of social imaginary significations in Castoriadis’ work hindered the capabilities of his theorisation to understand societal change. On the contrary, contextual creation allowed for the development of an understanding of the way social imaginary significations continuously change: they are constantly re-interpreted and humans who exist within different constellations of meaning put their reinterpretations into conflict. Hence, contextual creation can understand better the differences between diverse socio-technical complexes.

Klooger (2012) made one step further towards this direction and

suggested that Castoriadis' theorisation is 'overly homogeneous' and unable to understand the inherent 'plurality and indeterminacy' of socio-technical reality. He attributed this weakness to Castoriadis' description of social closure according to which society creates itself, according to the social imaginary significations predominant therein, as can be seen in the extract below:

“Finally, the unity of the social world is guaranteed by the tendency of the world of social imaginary significations and institutions to establish and maintain itself in closure. This closure primarily means that the world resists change...If our understanding of society is based on this conception of a unitary social source and cultural structure, how are we to understand societies that encompass disunity and diversity?... All societies encompass diversity and disunity; what differs across history and geography is only the degree to which this is so (doubtless also the precise nature of the diversity and disunity, which need not be the same everywhere). If our theories of social creation and change are to be useful, they will need to account for this characteristic of real societies.” (Klooger, 2012, p. 489)

Klooger, in this quote revealed the main deficiency in Castoriadis' approach. A society closed in itself which creates itself through specific social imaginary significations, is a society that resists change. Hence, researchers can see that the most radical and innovative aspects of Castoriadis' thought are wasted. Klooger claimed that there is diversity and disunity in all societies. These phenomena cannot be accounted for within a society that simply recreates itself according to some social

imaginary significations. As Ciaramelli (1989, p. 102) noted, Castoriadis was very good at explaining us that change, true creation and the project of autonomy were more than phantasies in our society. However, at the same time, he was unable to explain how and when these changes would occur. Following this argumentation, Castoriadis' theorisation is unable to understand how and when humans stopped producing medieval technology and proceeded to the modern technological age.

Following a similar reasoning, Smith (2010) criticised Castoriadis for his views on closure not at the societal level, but at the level of the human psyche. As I have already mentioned previously, the main contrast in Castoriadis' (1975) approach is that between psyche and society. In fact, Castoriadis claimed that this confrontation is a violent one. The psychic monad is obliged to pay attention to socio-technical reality because it does not survive otherwise. However, Smith argued that it is exactly the need to survive that obliges the radical imagination to seek resources out of itself and to open to socio-technical reality:

“While the newborn psyche enters the world as an unformed, chaotic psychic flux of indistinct representations and a drive towards closure, the need to create meaning drives an opposite move towards openness. In other words, the unformed psyche tends towards instituted closure while at the same time being intrinsically open to new structures, meanings, institutions, limitations and representations from which to form that closure. By extension, and speaking

loosely, we might say that the demand for meaning imposes a demand for resources from which to create meaning which the radical imaginary cannot supply for itself.” (Smith, 2010, p. 107)

In the quote above, Smith suggested that beyond the drive for closure, described by Castoriadis, there is also a tendency in the human psyche to open towards the ‘world’ because it needs meaning to survive and meaning is provided by already existing socio-technical reality. In fact the existence of symbols and of meaning is unnecessary outside the society as created by humans. Hence, the capability of the psyche to produce symbols and to develop and understand meaning signifies that it is already open to ‘extracting’ resources from previously existing socio-technical reality.

Nevertheless, even though the advantages of arguing in favour of contextual creation are so evident, Castoriadis insisted that creation was absolute and that interpretative contexts were irrelevant (Klooger,, 2005). He viewed any effort to understand creation as interpretation of existing entities, as another way to reintroduce the ensemblist-identitary reasoning in his work. Indeed, if researchers try to understand technological innovation, the existence of contexts at the level of the psyche can lead to the return of determinism, as can be seen in the following paragraphs.

If a context exists, then, in every new idea, there is a part that is

just created and a part that belongs to the pre-existing socio-technical reality, i.e. the context. This part was in some way internalised by the psyche, which, as Smith (2010) argued, seeks resources from the ‘world’. Hence, the qualitative characteristics of a new idea also largely depend on the environment in which the agent lives. This conclusion seems quite straightforward and it obviously makes possible to understand that somebody who lived during the Stone Age definitely could not have invented the internet. The problem, however, is that it does not explain the origins of the combinations between parts just created from the function of the human psyche and parts from the context, i.e. from pre-existing socio-technical reality. If the ways they are combined are determined from pre-existing socio-technical reality, I would adhere to the deterministic reasoning which Castoriadis rejected. If they are derived *ex-nihilo*, I would have simply returned to Castoriadis’ absolute creation by transferring the same question one level behind. Either way, I had to find another way to solve the problem of Castoriadis’ theorisation.

This logical impasse simply points to the fact that if an idea is derived *ex-nihilo*, than it has to be entirely derived *ex-nihilo*. The fact that some elements of the idea are relevant, similar or identical to some elements of pre-existing socio-technical reality has to do with the choices the radical imagination makes at the moment of inspiration. They are not

reflections but creations, 'images' that the radical imagination created and chose to combine with the aspects of the new idea that are entirely innovative. This conclusion is similar to the one Sartre (1940) reached in his book 'The Imaginary' and allows for a clearer and more straightforward understanding of the way pre-existing and innovative elements of a new idea are combined: they do not have to. The former do not exist in the psyche of the human agent.

This position is nothing but a regression to the problems posed by the interactions between absolute creation and social imaginary significations, i.e. the fact that it is not possible to understand diversity and disunity within socio-technical reality and, hence, the reason why specific qualitative differences, and, therefore, innovations are more likely to appear within specific times and spaces. It is important to understand what makes possible an innovation in the sector of marine energy technology of 2012 and not possible in any other place. The answer cannot be found if one considers that there is a context at the level of the psyche which has been created by pre-existing socio-technical reality. However, if contextual creation at the level of the psyche leads to a fallacy, then the answer to this problem should be found at the level of the social imaginary. And, as I explained previously, this answer cannot be Castoriadis' social imaginary significations.

Arnarson made the following suggestion, which could help

overcome this impasse:

“Within the limits of this paper, I can only outline an argument which would lead to a more effective contextualisation of Castoriadis' ideas. First and foremost, the rethinking of the social-historical should be brought into closer contact with the concepts of culture and power... Castoriadis...uses the concepts of culture and power, but defines them in such a limiting fashion that they remain marginal to his main concerns.” (Arnarson, 1996, p. 15)

Here, Arnarson argued that the only way to avoid the problems posed by the concept of social imaginary significations, would be to re-articulate in a more concrete way the concepts of culture and power within Castoriadis' theorisation. Castoriadis did not theorise adequately the concept of power and the way it is exercised within and among the various institutions created by humans (Arnarson, 2014). The understanding of the distribution of power within a given socio-technical reality and the subsequent emergence of diverse cultures, partially due to this distribution, might be the only way to understand how human radical imagination functions within a context posed at the level of the social imaginary. To be more precise, socially fabricated individuals, including technologists, innovate using their radical imagination within the confines of formations which exist at the level of the social imaginary and which exact power upon them and force them to adopt specific types of behaviour.

Adopting specific types of behaviour can only happen through learning, either theoretical or practical. Learning, however, is not an internalisation process directed by specific structures which operate at the level of the psyche and provide the context for the radical imagination. On the contrary the things humans learn are also absolute creations of the radical imagination which humans had to create in order to make their innovations functional within socio-technical reality. What I mean is that new ideas do not combine new and old elements which have been internalised in specific ways. Instead, humans engage in absolute creation of new ideas and recreate everything that already exists. But, to recreate something, human agents first have to know some of its characteristics. For example, only if somebody knows the speed of Pentland Firth's waves, will he or she be able to recreate it in his or her mind within an idea of a new wave energy device that interacts in an innovative way with these waves. Therefore, to understand innovation in a specific socio-technical locus, such as the sector of Scottish marine energy, it is necessary to investigate what the agents who are active there learned in the past and how they learned it. That way it will be possible to locate an innovation more efficiently for two reasons. Firstly, the things that the agents have learned are something much more concrete than simply their socio-technical 'environment'. Hence, understanding learning as creation allows for the understanding of the various diverse

and distinct socio-technical formations in which humans exist. Secondly, having to focus on what they learn means that it is possible to propose a methodology based on asking them what they know and how.

Even so, not all types of learning are equally possible to result in an innovation. Castoriadis' (1975) analysis about social imaginary significations was correct with regards to this issue. Humans do develop during their lifetimes an intricate knowledge of the basic structural characteristics of the societies in which they live. This is of extreme importance for this research because a technologist can innovate only in the domains which he or she considers susceptible to change. However, it is much less common within modern socio-technical reality to meet people who try to change, for example, the organisation of the firm based on wage labour than other things, such as the engineering characteristics of marine energy devices. In fact, in these domains, learning is *expected* to result in innovation as revealed by the institution of the PhD. But then the cause of this difference is unclear, i.e. it is still uncertain why specific human agents usually expect to innovate in specific domains of their life and not in others, even though their knowledge in all of these domains can be equally advanced and social imaginary significations have been learned through the function of the radical imagination just as any other type of knowledge. If I accept that there are some types of knowledge that are more stable and less prone to change, then I have to describe

what that means for technological innovation. It could perhaps mean that there are some types of knowledge that are learned but not being questioned as the agents innovate, and that perhaps it is these types of knowledge that guide them. In that case, it is certain that my approach is in need of a theory capable of explaining why humans question some types of knowledge and not others. And this brought me back to the issue of different socio-technical formations, culture, power and their impact upon the beliefs of the human agent.

3.3 Radical Creativity

Interestingly, the careful examination of Bourdieu's (1972) and Castoriadis' (1975) theorisations has led to a parallel yet inverse conclusion: the concept of the habitus is designed to explain the more stable characteristics of human behaviour whereas the concept of the radical imagination can better understand qualitative change. Similarly, Bourdieu (1972) was able to theorise what was missing from Castoriadis, i.e. he was able to describe and understand the idiosyncratic distribution of power within specific socio-technical formations which leads to specific cultural results. At the same time, Castoriadis (1975), unlike Bourdieu, managed to incorporate change and true creation in his theorisation. Perhaps then researchers should start juxtaposing those

approaches and looking at them not as substitutes but as complementary theoretical ‘goods’. The final elucidation of this juxtaposition is what follows.

Since change is a fundamental characteristic of technology which is a human creation, the starting point of my approach is Castoriadis’ theorisation which is more adept at understanding ex-nihilo creation. Therefore, the basis of this theorisation is the rejection of ensemblist-identitary logic. Being might contain an ensidic dimension, but it is non-ensidic and magmatic in its entirety. Furthermore, following Castoriadis’ (1978) reasoning, I need to emphasise the existence of a fundamental dichotomy. Each technological entity, as well as everything within socio-technical reality is constituted by two separate dimensions of socio-technical reality. The first dimension is the equivalent of Castoriadis’s (1975) social imaginary and will be called the *performed dimension*. It is enacted by human agency, i.e. the function of the radical imagination and its interaction with the previously existing performed dimension which is to some extent dominated by the already instituted social imaginary significations. The performed dimension encompasses every cultural and/or technological element found within socio-technical reality.

The second dimension is the *independent dimension*: it is equivalent to Castoriadis’s (1975) first natural stratum and naturally is beyond the reach of human agency and its rules cannot be altered by

humans or their creations. It encompasses every feature of entities that does not ultimately originate from human actions. That does not mean that the Being of entities within this dimension is determined. Nature might be as creative as the human mind. After all, this is something that Castoriadis had started to explore in his later works (Castoriadis, 1997). Calling the first natural stratum, independent simply means that changes of the entities of this dimension do not depend on human actions. To be more precise, the shape, colour, size and function of a machine belong to the performed dimension whereas the laws of nature upon which its function relies, belong to the independent dimension. And this is the reason why I chose to emphasise Castoriadis' (1978) distinction of these two dimensions in *Technique*, instead of the more classical distinction between first natural stratum and social imaginary. These terms can be misleading to a researcher who deals with technological change because there are natural entities that are definitely manipulable and subject to alteration by human agents as well as parts of the human society which are beyond the human reach (e.g. the need to create a society). Commentators of Castoriadis, such as Adams (2011), even though they recognised the fact that the late Castoriadis (1997) had started pondering the possibility of a creative physis, pointed out the fact that his views on the matter were not entirely clear:

“Despite Castoriadis’s strong connections with contemporary *naturphilosophical* problematics and his rejuvenation of ancient Greek imaginary schemes, his discussion radical *physis* is unsystematic....That being said; *à- être* – and creative *physis* – remain but sketchily contoured throughout Castoriadis’s trajectory.” (Adams, 2011, p. 161)

My position regarding the creative character of the independent dimension is agnostic. The independent dimension may or may not be creative, but such Naturphilosophical concerns are beyond the scope of this thesis. Clarifying the distinction however, between the performed and the independent dimensions is one of the key ingredients for an innovative understanding of technology.

This dichotomy is necessary because it is a very efficient way to avoid a self-negation. Without it, it would be necessary to envisage socio-technical reality either as performed or as independent alone. In the first case, I would soon encounter the fallacies of the radical versions of social constructivism: if everything is performed by human action, then Being is ensidic. It is always the result of a performative act. On the other hand, if socio-technical reality is independent I would have to face the fallacies of technological determinism. To be consistent with an analysis where Being is not ensidic, technological innovations have to be the result of the fusion of these two dimensions of socio-technical reality. As inceptions, forms and functions, technological innovations belong to the performed dimension of socio-technical reality. The natural

principles upon which they were built however are beyond the reach of humanity. This is congruent with Castoriadis's (1997) analysis, where there is always a difference maintained in kind between the creative actions of humans and creative nature, as can be seen in the following quote from Adams (2011, p. 155):

“Yet it is clear that for Castoriadis the self-creations of laws of the “autonomic” living being at the level of anthropic being is different in kind, not just degree; the tension between *physis* and *nomos*, regional *nomos* and transregional *physis*, emerges particularly clearly in this context.”

The existence of the independent dimension means that the radical imagination's ability to represent ex-nihilo does not suffice for the development of a good idea or in fact for any idea. It has to take into account the qualitative characteristics of the pre-existing world and to use them as inspiration. Although the qualitative difference of an innovation is not the result of a previous conditioning, the adaptation of the innovation into socio-technical reality is.

To take into account the effects of pre-existing socio-technical reality to the human ability to create and the critique on Castoriadis on the issue of creation, I hypothesised that the radical imagination functions within a *perspective*. The perspective is a referent of the large but not infinite number of allowances and constraints the two dimensions

of socio-technical reality impose and it works as a linkage between the past experiences and the future prospects of the human agent. It is the recreations of elements of the already existing socio-technical reality which are necessary for an innovation to be compatible with the world. It is the part of the social imaginary that does not determine the eidos of the new ideas created by the human mind, but it orientates them and gives them context.

It is important to point out that this context does not consist of a number of representations which have been internalised in the minds of human agents and determine the creations of their radical imagination. On the contrary the psyche's constant activity remains unconstrained. The perspective is one more creation that humans choose to create either as a result of the encounter between their psyche and reality or simply because they want to. Hence, the perspective is an instrument created by the radical imagination which provides the latter's creations with everything that is necessary in order to be attuned with socio-technical reality. To be more precise the radical imagination is not determined by a context, but it does create a context for its creations that guarantees their usefulness. The fact that the perspective functions usually as a constraint as well, is due to the fact that humans have to survive in a world of necessity.

Hence, the perspective forms part of the performed dimension.

Just as any part of the performed dimension, the perspective is a creation and it is susceptible to constant change. It is full of contradictions and should not be considered as a stable entity. Certainly there are elements of this perspective that are present most of the time, however nothing could assure anybody that these will always form part of it. This is not the radical imagination of Castoriadis (1975) and it shall be called thereafter *radical creativity*. An innovation in general and a technological innovation in particular start from the radical creativity of a human agent or a group of agents.

The analysis of the perspective of technologists allows me to proceed to the second point. Humans come into being into an already instituted socio-technical reality. To survive, they adopt some *sets of behavioural patterns*, i.e. collections of specific types of predictable actions that can offer predictable results. This adoption happens through learning and imitation. An important part of this process is the adoption of practices, i.e. sets of behavioural patterns that no longer require active thinking for their completion.

However, the level of complexity in a world where Being is not ensidic means that even in the dullest of jobs, every day is different, exactly because the world is a complicated place due to the interactions between the independent and the performed dimension. In a sense, everybody has to make personal innovations every day to achieve even

the most rudimentary targets. And even if there is the objection that there are in the modern world boring bureaucratic jobs where every task and every day seems the same, it could be argued that there are minute differences from task to task and from day to day. These differences could be found for example in the location of the boxes a worker has to carry (which have to be picked up from a slightly different place in the room where they work) or in the discussion he or she has to perform with one's colleagues. The personal innovations which are performed to overcome these differences are usually trivial, similar to what other people have done in the past and most of the time everyone ignores them.

Nevertheless, since the internalisation of sets of behavioural patterns is the result of the realisation of an infinite number of trivial personal innovations, then these behavioural patterns are slightly different in each human agent. For example, no two people who work as plumbers work in exactly the same way. They work similarly enough to be recognised as plumbers, but, after a closer look, he or she will spot tiny differences in their conduct. Equally, since the personal experiences of human agents differ, each human agent has developed distinct expectations for the sets of behavioural patterns that other agents should use. For example, there are people who expect waiters to greet them with a smile and others who do not. Hence, if agents are radically creative,

there is complexity and diversity both at the level of the personal behaviour and at the level of the expectations other agents have about specific behaviours.

The diversity in human behaviour, which is due to the personal innovations conducted by radically creative agents and the inherent complexity of the human psyche and of its interactions with the performed and the independent dimension, means that humans live in a socio-technical reality where innovation is ever-present. And even though the majority of those innovations are, as I have already explained, personal, there are also some which are neither trivial nor minute. They are societal in the sense that nobody in a given society has done them in the past. These are changes that cannot be ignored because of their importance. Historically, some have occurred by accident, however, most of them required a long period of learning and apprenticeship for their completion. Despite these amounts of learning however, the societal innovations are a subcategory of personal innovations. They are personal as well, in the sense that the qualitative difference that defines them originated in the radical creativity of specific agent(s). What the theoretical approach developed in this chapter offers is the capacity to develop a *systematic understanding* of these moments of ex-nihilo creation which might lead to societal innovations. This is something that other theories have been criticised for in developing reductive

explanations and attributing innovation to the contingency of human agency, as can be seen in following quote from Holmwood and Kemp:

“In relation to roles, we have argued that it is a mistake to assume that the expectations for any role are singular in character. In our view, there are plausible sociological reasons to think that role expectations may vary across different groups. Likewise, we have argued that it is a mistake to assume that variation in role performance is due to contingent factors like deviance or individual agency. Rather, locating divergent expectations may help to explain cases such as those where incumbents act differently in different situations. In relation to our wider argument, we noted early on that approaches such as functionalism and critical realism put forward “compromise” positions insofar as they attempt to avoid an over-commitment to the contingency of social life whilst not removing it altogether. Our issue with the form that this compromise takes is that the theoretical structure it relies on sets an a priori limit upon systematic explanation.” (Holmwood and Kemp, 2012, p. 421)

This systematic understanding can be achieved by searching for the differences in the sets of behavioural patterns that the agents developed through their experiences, and then by developing an image of the perspective of their radical creativity. The differences in the perspective of their radical creativity are able to reveal why specific innovations occurred in specific locales. Hence, it will be possible to avoid Castoriadis’ (1987) reductive explanation that considers technological innovations derivations of social imaginary significations without paying some attention to the differences among specific socio-technical

formations.

3.4 The Technological Field

In the previous sections, I concluded that an approach that aims to understand technological innovation as a change induced by radically creative human agents has to take into account the differences among different socio-technical formations and the impact these have on the perspective of the technologists. Now, a key feature of Modernity is that it is the socio-technical locus where innovation, technological or not, personal or societal, has been utilised and actively pursued more than ever before and, thus, has contributed in the creation of the first global system (Giddens, 1984). Modern societies are full of institutions that rely on innovations to achieve specific results. The dominating form of economic organisation, capitalism, depends on personal and societal innovations for its survival and this has a huge impact on the way they work and, hence, on the perspective of the human agents therein. Capitalist firms organise their personnel and equipment under their possession in ways which assure the achievement of an increasing amount of personal innovation per employee (for example by inducing competition among their workers), i.e. the more and more efficient completion of tasks (Weber, 1905). Moreover, many of them pursue

societal innovations to out-compete their competitors. Such an organisation increases a firm's profitability and guarantees its survival and the well-being of its owners (Schumpeter, 1939).

The problem is that although the ever-present competition seemingly suffices to impose a specialisation which takes into account the complexity of socio-technical reality and orientates the radical creativity to the achievement of a large amount of innovations, the consequences of its application are more complicated. Competition leads to monopolisation and specialisation which results in a socio-technical reality where the perspectives of radical creativity are much narrower: they are reduced to the enhancement and perfection of a very small amount of methods and applications. Workers, scientists and technologists know more and more about less and less (Castoriadis, 1987). The existence of the independent dimension of socio-technical reality and its complexity which humans are unable to manipulate do not permit an unlimited number of performative actions. There are limits to the ways radical creativity can ameliorate a method. Sometimes, it is important to be able to radically alter the whole process and push the technology into a new trajectory as Dosi (1982) described. The achievement of this transformation necessitates agents with more diverse learning and personal innovations. Therefore, a firm has to develop a balance between monopolisation, specialisation and diversity. Most firms

do that to a certain extent: some employees are allowed to work in a more improvised and diverse way. For example, scientist employees are allowed much more freedom to define the way they work, than workers of the assembly line, because scientific and technological progress requires a certain amount of autonomous self-determination (Bourdieu, 1997; 2001) which leads to an innovative business culture, as examples from specific technological sectors have proven (see e.g. Hamel [1999] on innovation in the Silicon Valley).

However, there is a limit to the balance a firm can achieve between specialisation and diversity. The independent dimension enables and constrains a vast diversity of actions which, through the function of the radical imagination, result in an even greater diversity of innovations. All these diverse innovations cannot be handled equally well by a single institution. That is why there is specialisation among firms and institutions and even states in capitalism (Ricardo, 1817). Each firm produces different kinds of commodities and state institutions have different duties than firms. The specialisation of institutions results in a higher productivity for the sum of the economy, than in the case of everything produced by a single institution.

To conclude, control and competition are only two forms of interaction among agents and institutions. Agents and institutions which desire to achieve a specific result have to be involved in a complex field

of relationships, a discursive field, determined by the juxtaposition of radical creativity with the performed and independent dimensions of socio-technical reality. Each firm needs to interact with other institutions and agents not only via competition but via cooperation and clientage as well. However, competition, cooperation and clientage depend on the various forms of power each agent and institution possess, and on the way they have already experienced socio-technical reality and developed their perspective. Hence, I have returned to Arnarson's (1996) argument that a prerequisite for the understanding of any type of creation (and, in this case, of technological innovation) is the understanding of culture and power.

Bourdieu's (1972) main ontological contribution to this research is that he developed a theory which provided theoretical tools capable of addressing both the issue of the distribution of power and the issue of the development of distinct types of reasoning in specific socio-technical formations and how this is related to the social imaginary significations which dominate socio-technical reality in general, as can be seen in the following extract from one of his interviews:

"I define a field as a network, or a configuration, of objective relations between positions objectively defined, in their existence and in the determinations they impose upon their occupants, agents or institutions, by their present and potential situation (*situs*) in the structure of the distribution of species of power (or capital) whose

possession commands access to the specific profits that are at stake in the field, as well as by their objective relation other positions (domination, subordination, homology, etc.). Each field presupposes, and generates by its very functioning, the belief in the value of the stakes it offers. In highly differentiated societies, the social cosmos is made up of a number of such relatively autonomous social microcosms, i.e., spaces of objective relations which are the site of a logic and of a necessity that is specific and irreducible to those which regulate other fields. For instance, the artistic field, or the religious field, or the economic field all follow specific logics: while the artistic field has constitutes itself by refusing or reversing the law of material profit (Bourdieu 1983d), the economic field has emerged, historically, through the creation of a universe within which, as we commonly say, “business is business,” where the enchanted relations of *phylia*, of which Aristotle spoke, of friendship and love, are excluded.” (Wacquant, 1989, p. 39)

Here, Bourdieu suggested that it is possible to understand the development of specific cultures and types of reasoning through the interactions among human agents and the practical behaviour they develop within differentiated spaces with a diverse distribution of power. This is an efficient way to overcome the impasse of objectivism and subjectivism and hence, develop a rich understanding of human behaviour and how it strategically changes. Unfortunately, Bourdieu’s approach failed, for reasons I explained in previous sections, because he insisted on using the rigid concept of the habitus. However, if it is possible to replace the concept of the habitus with a different concept capable of understanding human innovative behaviour and how it leads through learning and personal innovation to the development of specific

sets of behavioural patterns, then there is no reason not to use the concept of the field, as an adequate way to theorise the distribution of various forms of power and the development of specific cultures.

Therefore, the *technological field* is a set of relations, i.e. a discursive field that tries to achieve the adoption of specific behaviours by non-human actants and their integration in capitalist institutions. It is discursive because its emergence, form and evolution depend on the function of radical creativity within a socio-technical reality comprised of the two dimensions of socio-technical reality and not simply on nature or practice. It is not a field where practical knowledge and the logic of practice (Bourdieu, 1980) form objective structures. Practical knowledge is a derivation of acts of radical creativity and the confrontation of its structures by agents depends on their learning and personal innovation, i.e. on the function of radical creativity.

Even though the behaviour of the agents is not determined entirely by the structure and characteristics of the field, I should still use that concept mainly for the following reasons. Firstly, the radical creativity of each agent is formed in an already instituted socio-technical reality: therefore, agents share common experiences and talk a ‘common language’. Secondly, the agents who work within the institutions which participate in the field all affect each other. For example, if the purpose of the director of a private developer firm is to guide the development of

a new type of machine, then the purpose of the head of a public institution is to make sure that the development of this machine respects some environmental regulations. Thirdly, even though the unique ‘common language’ exists, it is exactly due to the complexity of socio-technical reality and the diversification of the institutions of the field that none of the agents adopt it in exactly the same way as someone else. Being active in each position in the field is different. To state it briefly, their radical creativities have similar perspectives but are not identical. Even though the number of similarities that are due to their co-existence in the same field is much larger than the number of differences, the latter is of paramount importance to the qualitative characteristics of the innovations, because they can be a major cause for the diversification of technological innovations. Finally, the independent dimension of socio-technical reality allows only for a finite number of manipulations of non-human actants. The perspective of agents develops around these manipulations which constitute its ‘spine’ and are common for diverse agents.

Even if the word ‘field’ is suitable as a metaphor in both its Bourdieuan and its Technological versions, there are a number of significant differences between the two types of fields. In the Bourdieuan (1972) field, the agents internalise the external structures of the field via their habitus and this primacy of their practical reasoning means that the

internal structure and hierarchical relations of the field are much more stable and less susceptible to change. On the contrary, the approach of the technological field introduces two catalytic factors which destabilise the rules of the field. To start with, the agents do not internalise the rules of the field via their habitus but via their radical creativity, i.e. via learning and personal innovation. Hence, the diversity in the way agents internalise the field is even greater than the diversity of the different positions within the field itself. And greater diversity leads to a greater number of future paths for the field to follow. The second catalytic factor is the independent dimension itself. The interaction between the radically creative human agents and elements of the independent dimension might produce results that are unlike anything included so far within the field.

Even so, there is one stable characteristic in the organisation of the technological field. Since the success of technological innovations depends not only on their invention but on their commercialisation and incorporation in socio-technical reality as well, a successful technological innovation requires changes in the behaviour of both humans and artefacts. Institutional functions which deal with the change of the behaviour of non-human actants, as Actor Network theorists would say, form the core of the technological field. Their purpose is the engineering of non-human actants in ways that make them produce a desired result. Institutional functions which deal with the change of the

behaviour of human agents form the periphery of the technological field. Their purpose is the preparation of new sets of behavioural patterns for humans which will permit the incorporation of a technological innovation to their behaviour.

Furthermore, another point of divergence between the two types of field is that the technological field is not defined as such because the agents fight for one or two diverse types of cultural capital, such as for example the scientific Bourdieuan field (bureaucratic and scientific capital) (Bourdieu, 2001); neither does the multiplicity of different types of capital pursued by the agents necessarily lead to the emergence of a type of capital that specifically defines the field, as in the case of the statutory Bourdieuan field (Bourdieu, 1994). Yes, cultural capitals might exist within a technological field, but they are not their defining feature. Instead, there is the possibility that within a technological field co-exist a vast number of agents, several of whom have absolutely no idea of the cultural capitals that are of importance to others. Hence, it would be better to regard the competition for cultural capital as just one type of interaction among the agents in the field. It is these interactions and the mutual influence exercised between various agents and institutions that define the technological field.

Finally although Bourdieu's (1980) position in favour of the primacy of practice cannot be combined with this analysis, this is not

true for two other features of his notion of the field. Firstly, Bourdieu and Wacquant (1992) argue that each field is further separated into subfields. The emergence of a subfield is due to the generation of a qualitative difference that separates it from the rest of the field. The qualitative differences of subfields are in accordance with the efforts in this analysis to identify the differences in kind that radical creativity induces as well as the effects of complexity of the two dimensions as a cause of diversity. Within globalised capitalist institutions, a general technological field is traceable which addresses every potential kind of technology. It is then further separated to increasingly reduced subfields that treat specific technologies. Secondly, Bourdieu's field (Bourdieu and Wacquant, 1992), just as the field of this analysis, is not an apparatus which serves as the backbone of a system. It is a set of relations that continuously changes and not necessarily in an organised way, due to the existing complexity.

3.5 Summary

The purpose of this chapter was to complete the answer to the ontological question, i.e. to develop a theory capable of utilising all the necessary elements of a new understanding of technological innovation which I derived in Chapter 2. I developed this theory via the creative

critique of the approaches of Bourdieu and Castoriadis. I argued in favour of the efficacy of Bourdieu's concepts of the field and cultural capital as instruments which provide insight regarding the orientation of technological innovation and rejected the habitus as an inadequate theorisation of the way human agents interact with technological entities and develop their practices. Moreover, I rejected the habitus because it is unable to understand the rupture aspect of technology.

To cover this gap I developed the concept of *radical creativity*. This concept is founded upon the ontology of Cornelius Castoriadis (1975) who claims that the human psyche is capable of ex-nihilo creation. The incapability of Castoriadis' theorisation to provide insight regarding the interactions between pre-existing socio-technical reality and the psyche's capacity for ex-nihilo creation induced me to develop the concept of radical creativity, i.e. to hypothesise that to innovate, the human psyche has to create ex-nihilo and then to combine its creations with recreations of entities that have already appeared within socio-technical reality. As a result, ex-nihilo creation functions within a perspective of such recreations. The entities that it has to recreate to form this perspective are obtained via learning, imitation and the conduction of a vast number of petite personal innovations in the everyday life of the agents. Finally, technological innovation takes place within an institution, the technological field. This institution consists of a number

of other institutions which form relations of cooperation, competition and clientage and are inhabited by radically creative agents.

Having developed a theory capable of providing an understanding of technological innovation, the temptation would be to apply it as fast as possible to the sector of marine energy technology in the UK. However, it is important to remember two things. Firstly, the purpose of the application of this theoretical approach is not prediction, but understanding. The complexity of human radical creativity guarantees that it is not possible to determine the exact qualitative characteristics of an innovation as well as the time and space where it will occur. However, the analysis of the perspectives of human agents allows for an identification of positions in the technological field where the realisation of specific innovations is more probable. Secondly, it is impossible to conduct research before deriving an epistemology and a methodology from my ontological principles. The answer to this epistemological-methodological question will be the object of the following chapter.

Chapter 4: Epistemological and Methodological Remarks

This chapter will try to answer question two, i.e. the epistemological-methodological question, and will describe the epistemological and methodological premises of this innovative understanding of technology. I chose to start from the epistemology and then to proceed to the presentation of the methodology because the choice of methods used for data collection and analysis depend on the way knowledge and science are defined.

The first section of this chapter is the epistemological section. I will argue that the epistemology of the approach of the technological field is a subjective epistemology, because it is only through the experiences the agents gained inside the field that researchers can understand how their radical creativity affected the way they worked and, hence, technological innovations. However, this subjective epistemology has to be combined with specific objectivist elements, because the independent dimension and the existence of the perspective of the agents' radical creativity 'obliged' them to share some common experiences, since they had to respond to similar socio-technical phenomena within the field. Finally, I will explore the implications of my epistemological analysis regarding the reflexivity of my approach in terms of both Bloor's (1976) and Bourdieu's (2001) definitions of

reflexivity.

The second section of this chapter will present the methodology which was derived from the epistemological arguments of the first section. I will conclude that the research had to be conducted in two stages. The existence of the independent dimension implied that the first stage should be a short period of documentary (mainly online) research which would aim to gather some initial information about the field. However, the main part of the data collection was completed during the second stage of the research. I chose to use the method of focused semi-structured interviews during this stage of the research because it was one of the methods which could provide data about, firstly, the events that occurred in the field and, secondly, the ex-nihilo creation within the agents' radical creativity as well.

The third section discusses how this investigation unfolded. I will describe the procedures through which I conducted the initial documentary research. Afterwards, I will present the interview questions that I derived based on my theoretical arguments and these results, and how I managed to gain access to my interviewees and conduct my fieldwork. Finally, I will discuss the methods I used for data analysis and the ethics of my research.

4.1 Epistemology

If the technological field determined the speed and orientation of technological change, then a prerequisite for the understanding of technological innovation would be the understanding of the technological field and its organisation. To achieve that, it is essential to remember that the technological field is an instituted socio-technical locus, constructed by radically creative humans. And since their radical creativity is based, following Castoriadis (1975), on the ontological position of a non-ensidic Being, the epistemology of my research had to agree with this position.

Adhering to a non-ensidic Being, i.e. escaping the ensemblist-identitary approaches of modernity (Castoriadis, 1975), is synonymous to understanding that knowledge of the Being of modern socio-technical reality is neither stable nor something without any performative effects. And, if the former fact is pretty straightforward (if the object of a study changes, then so do the theories that address it), the latter means that a theory cannot possibly be a simple representation of the events within modern socio-technical reality. The reason for that is the existence of the performed dimension which exists due to the function of human radical creativity. If the latter is the source of complexity within the performed dimension—as Castoriadis (1993) suggested, unlike Complexity

theorists—then any type of human action within this dimension can have performative effects and so do theories.

Therefore, it is unwise to treat social theories as simple representations of social phenomena and social scientists as agents who bear no influence upon the phenomena that they study. As Cooper (2008) argued, this is simply another way of adhering to ensemblist-identity rationales:

“This picture is one in which the sociologist occupies a vantage point which is quite separate from the object of study (society or some aspect of it), and from which it can be clearly viewed: to extend the metaphor, he or she merely has to select some interesting theoretical spectacles, and perhaps some appropriate measurement devices from the available tool kit of methods, before proceeding to analyse the phenomena of interest from this position of detachment. ... Indeed, some have argued that the existence and prevalence of this picture of disengaged empirical observation is itself the product of particular pernicious currents within modern Western societies (Adorno, 2000).” (Cooper, 2008, p. 8)

Hence, accepting the hypothesis of the non-ensidic Being, means accepting that theories do not simply represent a world, they also shape new realities. Any new theorisation is not a simple representation, but an innovation which undermines the foundations of previous scientific innovations. These innovations can either be small and incremental or they can even introduce new scientific paradigms (Kuhn, 1962). The problem is how to make sure that these changes help social scientists

achieve a more complete understanding of the field under investigation; and the answer to this question depends on the scientific field.

All scientific fields produce innovations which alter more or less the fields themselves. After any type of new scientific publication the scientific field changes irrevocably, even if the change is sometimes so insignificant that passes unnoticed. Social constructivists have rightfully argued that among the things that each innovation constructs is also what commonsensically is referred to as the object of scientific research within each field (Barnes et al, 1996). For example, physics constructs what lay understanding translates as the 'laws of nature'. It constructs the ways everyone defines these laws, as well as the ways with which everyone believes that they can interact with nature. This performative effect can be seen in any type of science. The difference however (and this is also one of the positions that differentiate this theory from social constructivism) is that the object of research of some fields (but not the knowledge generated about this object) includes a 'residue' which is beyond human influence and changes for reasons that are independent of the actions of humans. This 'residue' is part of the independent dimension of socio-technical reality and exists beyond the performative effect of human action and science. Scientists in the fields of the 'hard sciences' construct interpretations of such residues. This is a simple abandonment of the problematic hypothesis that the world beyond

humans has no influence whatsoever in the way it is constructed by humans. The existence of these residues is also the reason why researchers do not have to read the literature of every generation of physicists to learn contemporary physics. It suffices to study the latest literature.

On the other hand, the object of study of social scientists belongs to the performed dimension of socio-technical reality. Hence, it affects and is affected by theories, including their own, as can be seen in the following short analysis of Marxism by Bourdieu (1989):

“Classes in Marx's sense have to be made through a political work that has all the more chance of succeeding when it is armed with a theory that is well-founded in reality, thus more capable of exerting a theory effect - theorein, in Greek, means to see- that is, of imposing a vision of divisions.” (Bourdieu, 1989, p.17)

Therefore, there is nothing eternal and insusceptible to humanly induced change and social theories both serve as approximations of human behaviour and shape socio-technical reality. Nevertheless, innovating within the scientific field of the social sciences is not pointless due to the following factors:

1. Social scientific research does describe a portion of socio-technical reality of the time and place when and where this research took place.

2. Social scientific research also describes human interactions with non-human entities which are enabled and constrained by the independent dimension. The effects of the latter can be found after the examination of the results of their research.

3. Even the discovery of the fallacies of theoretical approaches was an unintended consequence of social scientific enquiry itself. Any type of social research can be a stepping stone towards better understandings of the performed dimension.

However, realising the fact that theories have performative effects was not the only consequence of accepting the hypothesis of a non-ensidic Being. It also obliged me to evaluate technological change and stability in a different way to other scientific approaches such as those described and criticised by John Holmwood (1996), i.e. without simply describing the aspects of stability in a phenomenon and attributing change to the contingent character of human agency. Instead, this research considered humanly induced change as a given and attempted to describe its patterns within a given social locus. The limits of this locus are defined, enabled and constrained by the independent dimension. The patterns of change depend on the ex-nihilo creation of the radical creativity of the human agents, the enabling and constraining aspects of the independent dimension and, as the result of both these factors, on the power relations between the human agents within a social

phenomenon. To give an example, the limits of the phenomenon of a technological field are determined by the aspects of the independent dimension that distinguish one technological artefact from another, whereas the function of radical creativity and the independent dimension determine the relations of competition and cooperation that promote specific types of innovation over others.

Furthermore, the epistemology is also the main difference between the technological field and its Bourdieuan equivalent. In Bourdieu's (1980) approach the emphasis was on the structure and its objective characteristics that were internalised via the habitus. This was why in one of his most important books, *Homo Academicus* (Bourdieu, 1984) he relied on a number of statistics to help him reveal that structure. His epistemology was not a naïve objectivism, but rather an idiosyncratic objective social phenomenology:

“We have thus moved from social physics to social phenomenology. The ‘social reality’ objectivists speak about is also an object of perception. And social science must take as its object both this reality and the perception of this reality, the perspectives, the points of view which, by virtue of their position in objective social space, agents have on this reality.” (Bourdieu, 1989, p. 18)

Research that uses the technological field is unable to follow these epistemological premises, because the external structures of the field are not internalised through the habitus but through the radical creativity of

the agents. Hence, the conclusion of all the epistemological analysis so far in this chapter is that since the perspectives of the radical creativity of the agents are strictly personal creations, to understand them it will be necessary to adopt a primarily subjectivist epistemology. Subjectivism becomes even more suitable as soon as I consider that the phenomenon under question is innovation and innovation is by definition the creation of a new reality. The creation of a new reality however, is possible only due to the performativity of human thinking within the performed dimension. All new creations started as thoughts within the minds of human agents.

Subjectivism, however, is only one part of the story. The existence of the independent dimension means that technology is the material side of human creations and institutions and obliges the human agents who exist therein to respect a more or less stable routine as they perform their everyday duties. Human performativity exists but the independent dimension dictates that human agents are unable to change everything at the moment they desire. Although the views of the participants in the field might be infinite, their effects can only be finite. In the end, only specific behaviours of humans and non-human entities have generated future effects to socio-technical reality. These effects cannot be neglected because they are the past of the technological field. For example, the discovery of the automobile in its historical form,

although caused by myriad different views, was a moment of history that caused effects and transformed socio-technical reality. The views of the engineers who prepared it were really only hypotheses but the fact that they created a new interaction with the independent dimension means that it would not be worthless to study them. A part of them has actually been performative in the past. And it is exactly this past that obliges the researcher to recognise different technological sectors and their features and, hence, to orientate their research to their investigation. Hence, by studying the objective routine of the human agents and the material products of the ordinary function of institutions the researcher will be able to develop a static image of the institutions under investigation. Such an objectivist epistemology offers the researcher only a brief glimpse at a static version of an institution without any aspiration to describe change which depends on the agents' radical creativity. Nevertheless, this brief glimpse to the static image of the institutions of the field could perhaps be used to provide some elementary information about the perspectives of the radically creative agents of the field.

If the independent dimension is the first reason why I am obliged to leave the door half-open for objectivism, the function of radical creativity itself provides another. People within a technological field share some common experiences which rely on the already instituted relations with the independent dimension and form the perspective of

their radical creativity. The more common experience they have the greater the similarities of the perspective of their radical creativity. According to this analysis, great similarities in the perspective of the radical creativity could sometimes be equivalent to similar roles inside the technological field. Therefore, the investigation of the views of the agents could uncover the approximate organisation of the field in a specific moment of time. The impact of these similarities and influences should be to a large extent obvious within their radical creativity and this is an *objective* fact that should be taken into account when researchers question themselves about whether or not they should apply the approach of the technological field to the study of a technological sector. Any research conducted according to my approach should understand that the subjective thoughts of the participants within the field are heavily affected by the objective existence of various types of interaction among them.

To finish an explanation of my epistemological precepts I have to discuss the issue of reflexivity. There are two types of reflexivity to be addressed. The first relates to Bloor's (1976) definition of reflexivity and the second to Bourdieu's (2001) reflexive sociological critique. The need to address the first type of reflexivity is related to the fact that my critique against both social constructivism (Pinch and Bijker, 1984) and Complexity theory (Cilliers, 2005) has been based upon the observation

that they do not abide by David Bloor's definition of reflexivity.

I believe that most elements of this new theoretical approach are consistent with Bloor's (1976) version of reflexivity. The existence of a technological field where institutions interact and eventually produce technological innovations, as well as the theorisation of the independent, the performed dimension and of radical creativity, are simply theories of the performed dimension. The emergence of these accounts was enabled and constrained by the independent dimension and the already instituted performed dimension of the societies in which they appeared. These theorisations are correct as long as they describe accurately the independent and performed dimensions of modernity (the former) and of human societies in general (the latter). If socio-technical reality changed they would have to change.

Even though the hypothesis of a non-ensidic Being is also part of the performed dimension, it is impossible to claim that its accuracy is also subject to change. In that case, Being would be determined and my analysis would suffer from the one-sidedness analysed in the previous sections. The non-ensidic and magmatic Being is, as Derrida (1967) would say, the dogmatic moment of my theorisation. For such a fundamental theoretical assumption, it is necessary either to abandon entirely the efforts to be reflexive, or to develop a different definition of reflexivity. Such an investigation however, is beyond the scope of this

piece of research.

The second type of reflexivity that I should address is Bourdieu's. In his work *Sketch for a Self-Analysis* (Bourdieu, 2004), Bourdieu attempted to analyse himself using his theoretical approach and he started by describing the field in which he commenced his career. In that case, a scientist (Bourdieu) tried to interpret the position of a scientist (Bourdieu) within an objective structure such as the scientific field. Hence, the object of his analysis was a scientist and the way to understand it was the analysis of the scientific field. However, my object of study was not a scientist but technological innovation instead. Hence, if I would like to apply Bourdieu's reflexivity, an analysis of my positioning against the human agents and the technological field, which I examined, was absolutely necessary.

When I started my research I had no relation whatsoever to any technological field, let alone the technological field of marine energy technology. My degrees are not in a scientific/technological sector which might induce some performative effects upon specific types of technological artefacts and I have never worked in any job related to a technological sector. Hence, I am a simple social researcher member of a scientific field perhaps but definitely not participating in the technological field. Not having any experience of participation in the technological field meant that my radical creativity was free of the

beliefs about the nature of the development of the field which might have resided in the various positions within it. However, coming from a different socio-technical locus meant that there was the danger of imposing on the technological field the knowledge and the beliefs that were learned in other socio-technical loci, and, in my case, the scientific field. Hence, I had to make sure that I worked in a rigorous scientific way, but that I did not hypothesise that the technologists within the technological field adhered to the same beliefs as me.

That was true only at the start of the research. Once I started collecting data, my radical creativity filled with recreations of aspects of the life in the technological field. I was no longer a simple stranger and it was impossible to remain totally uninfluenced. To make sure that my analysis maintained its value, it was necessary firstly to base it on the views of the agents of the field and not on my account of their actions, i.e. to use *abductive* reasoning, as described in the following quote:

“With abduction the researcher grounds a theoretical understanding of the contexts and people he or she is studying in the language, meanings, and perspectives that form their worldview. The crucial step in abduction is that, having described and understood the world from his or her participants’ perspectives, the researcher must come to a social scientific account of the social world as seen from those perspectives.” (Bryman, 2012, p.401)

And, to avoid biases in my analysis, it was necessary secondly to remain

faithful to the approach of the technological field and seek the views of agents who possessed distinct and diverse positions within the technological field. Hence, the solution to this problem was to use an appropriate *sampling* method of respondents. On the other hand, possessing knowledge about the field had its advantages, because I could discover valuable sources of information much more easily. Thus, in the end the correct utilisation of the ameliorated capacity to collect interesting data without ‘going native’ and losing the scientific perspective depends on the ethos, courage and capabilities of the individual researcher.

Social research always involves contact between the researcher and the researched. It is necessary to keep in mind that the theoretical approach of the technological field implies that any research is an innovation and has an effect on its object. In my case this effect was mitigated by the fact that I was a researcher without much authority in his sector and hence, it was highly unlikely that the technologists that I studied would change their radical creativity in a profound way simply because they interacted with such a researcher. However, the magmatic character of radical creativity means that the respondents were affected by my intervention even if this effect was insignificant. All of this influenced the methodology of the thesis, which will be spelled out in the next section.

4.2 Methodology

Deriving a methodology that is coherent with a researcher's ontology and epistemology is difficult because any types of ontological and epistemological arguments oblige researchers to develop a specific image of socio-technical reality and how it is possible to interact with it and obtain knowledge about it. It is the moment when the theoretical enquiry has to use some tools to meet, come to terms and 'exploit' socio-technical reality, what ANT theorists (Law, 2004) call 'outthereness', so that researchers can obtain data that are susceptible to meaningful analysis. However, socio-technical reality is bound to be approached in only a limited number of ways due to the existence of the independent dimension. Hence, while the development of ontological and epistemological arguments consists mostly of, as Castoriadis (1975) would put it, the unbound activity of the human psyche, the methodological enquiry is a troublesome effort to adapt a theoretical framework to the external conditions of the 'real world'. This difficulty could not be better illustrated than by the fact that, while there is an infinite number of social theories that has been developed over the ages, there is only a very short list of broad categories of methods that can be used to derive meaningful data for a social researcher: quantitative

(statistical and econometrical) methods, interviews, surveys, ethnographic methods, documentary research and experimental methods (Bryman, 2012). Therefore, the question this section aims to answer is which of these methods could comply with the dictates of the ontology and epistemology of the technological field.

My theorisation implies that any method used for data collection has to be able to trace the function of the agent's radical creativity, the root of humanly induced change within socio-technical reality. And it has to do that, not by looking for stability and attributing change to unexplained aspects of human behaviour, but on the contrary by exploring and revealing the patterns of change. Radical creativity involves the ex-nihilo generated representations of entities found in pre-existing socio-technical reality, i.e. the perspective, and the ex-nihilo creation of entirely new entities. All sociological methods, both qualitative and quantitative are capable of providing insight about the perspective, i.e. the things that every human agent recreates. None of them, however, are capable of describing the human capability to create ex-nihilo, because the latter is a strictly personal experience which varies from time to time. After all, a description is a determination and, as Castoriadis (1975) argued, whilst discussing the psyche's capability to create ex-nihilo, the exact purpose of treating socio-technical reality as non-ensidic means that it is impossible to determine in any way the

radical imagination:

“In particular, the regions considered here -- the radical imaginary and the social-historical -- imply a profound questioning of the received significations of being as determinacy and of logic as determination.” (Castoriadis, 1975, p. 174)

The fact that the function of radical creativity is impossible to define in its entirety, does not mean that social researchers should abandon the effort to understand it. Even though it is an elusive entity it is possible to observe it indirectly. Firstly, it is possible to observe ex-nihilo creation after it has unfolded within socio-technical reality, i.e. to observe its impact in the world. However, this method only provides insight about *what* the capability to create ex-nihilo of the agents does and not about *how* it does it. To examine it in a more complete way there is the second solution, i.e. the option to find those methods that let the agents under investigation narrate themselves how they create ex-nihilo and how they perceive the impact of this creation upon socio-technical reality.

Qualitative interviews comprise one method which offers the interviewees the opportunity to develop their own narrative about the function of their radical creativity and the manner in which the ideas generated in their minds relate with socio-technical reality, i.e. they offer the opportunity to apply an abductive research process (Bryman, 2012). To be more precise, I mean non-standardised interviews, i.e. unstructured

and semi-structured formats of interviews which allow for a guided conversation (Fielding and Thomas, 2008). Since there is no way to directly observe the representations created within the minds of technologists, I will have to rely on them and expect that some of their answers to my questions will be accounts which describe how their radical creativity functions. After all, the ability to create ex-nihilo is something that builds its perspective through an agent's experiences and semi-structured and unstructured interviews are an ideal way to investigate how the agents experience a professional sector (e.g. see DiCicco and Bloom, [2006] about the medical sector), i.e. how the agents of the field of marine energy technology experience their work there.

There are limits to this approach. An interviewee might either for whatever reason choose not to be frank (Fielding and Thomas, 2008), i.e. choose to answer in a way that prevents me from understanding how his or her radical creativity functions or might provide an already fabricated professional and institutionalised account of his or her work which isn't any more useful than what can be found in an official document. In both the former and the latter case, the success of the interview is in jeopardy because, as Fielding and Thomas (2008, p.126) argued:

“Respondents may offer only logical reasons for their actions, withholding evaluative or emotional reasons that

may give a truer insight.”

However, I think that an interview is as close as a researcher can get to radical creativity. And by interview I insist that I do not mean a completely structured interview where the interviewee cannot freely elaborate his or her opinions and where there is the danger of imposing the interviewer’s perspective (Fontana and Frey, 1994). This would be ineffective to a research that aims to reveal their way of thinking and only aspires to set some topics of discussion.

On the other hand, among the non-standardised formats, an interview that is conducted as an entirely free conversation, as described by Ely et al. (1991) and Robson (2011) is in danger of not addressing several key issues that might shed light on the ways technological change unfolds within the field of marine energy technology. In fact, the less informed the interviewees are before the interview about its topic the more possible it is that they will omit something really important. As Tim May put it, using the method of semi-structured focused interviews will help me collect data about how radical creativity developed and determined all the subtle tiny details that separated each agent’s approach to their work:

“These types of interviews are said to allow people to answer more on their own terms than the standardized interview permits, but still provide a greater structure for

comparability over that of the focused or unstructured interview.” (May, 2011, p. 135)

However, there are other types of qualitative research methods, such as the ethnographic methods. Ethnography involves some type of participant observation. The researcher immerses him or herself for a significant amount of time in the environment of the agents he or she aims to understand (Blaikie, 2010) and collects his or her data by observing them in their everyday contexts and by listening and participating in their informal conversations (Hammersley and Atkinson, 2007). During the analysis of the data the researcher aims to develop interpretations of the:

“...meanings, functions and consequences of human actions and institutional practices, and how those are implicated in local, and perhaps also wider contexts” (Hammersley and Atkinson, 2007, p. 3)

Ethnography has been described as a type of research that rejects maintaining scientific and positivistic superstitions and presumptions about social phenomena (Atkinson and Hammersley, 1994). Its main strength is that it gathers very rich data whilst minimising the danger of misunderstandings since the immersion of the researcher in the field of research is quite long. This is also the reason why many social scientists, such as Silverman, consider it a more efficient than the interview method

for the study of social phenomena:

“The apparent identification of non-quantitative social science with the open-ended interview generates a whole series of problems. Methodologically, it underrates the value of data gathered from naturally occurring situations. Analytically, it appears to accept that the only alternative to treating organizational structures as ‘real’ even ‘natural’ facts is to focus on an individual’s private experiences of organizational life. It thus leaves vacant the vast terrain of socially organized practices that cannot be reduced to either ‘objectivist’ organizational structures or ‘subjectivist’ individual meanings.” (Silverman, 1998, p. 9-10)

Here, Silverman (1998) claimed that the greatest disadvantage of interviews which ethnography was capable of overcoming is their inability to articulate a description of the everyday experiences and practices of the agents. This inability is even more important when researchers try to examine the way people interact and learn how to use technological artefacts as Silverman claimed while discussing the work of Ngwenyama and Klein (1994):

“Ngwenyama and Klein (1994)... note how current theory in knowledge system development (KSD) is based on research that asks experts and novices to ‘think aloud’ or to give voice to their ‘social interpretations’...The problem with such interview-based research is that ‘experts are unable to articulate all their expertise’ (Ngwenyama & Klein, 1994, p. 131). If we really want to study ‘the expertise upon which knowledge workers rely’ (p. 129) and, thereby, to develop ‘a theory of expertise’ (p. 130), we must turn away from asking questions and

examine experts' behaviour in situ. In this way, we are better able to access how implicit background knowledge is used in particular contexts..." (Silverman, 1998, p.13)

Hence, Silverman considered interview-based research unable to understand the expertise of agents. The word expertise in the case of the phenomenon of technological innovation could easily be used as a synonym for *craft*. If the experts are unable to narrate how they developed their craft, then there is no point to utilise the method of qualitative interviews.

A similar conclusion was reached by Latour and Woolgar (1986) when they discussed the use of ethnographic methods in scientific laboratories:

"In our original use of the term, we particularly stressed the utility of an "ethnographic" approach for maintaining analytic distance upon explanations of activity prevalent within the culture being observed... Our current position on the notion of "ethnography" is slightly different. Its main advantage is that unlike many kinds of sociology (especially Marxist), the anthropologist does not know the nature of the society under study, nor where to draw the boundaries between the realms of technical, social, scientific, natural and so on... Indeed, this approach may very well be compatible with a close collaboration with the scientists and engineers under study. We retain from "ethnography" the working principle of uncertainty rather than the notion of exoticism." (Latour and Woolgar, 1986, pp.278-279)

Thus, Woolgar and Latour both in their original and in their final use of

the term ethnography insisted that its advantage is the capability to immerse oneself in a social space without necessarily having to accept the interpretations that the agents who are active in that space give to the phenomena therein. Other methods which use either the words of the agents themselves or the documents they produce are in danger of accepting the views of the agents and neglecting more important factors such as their practices. I will now therefore consider how this critique of interviewing applies to my research and whether or not I too should use ethnographic methods.

The answer to the first question is negative. Interviewing *is* useful to my research because I intend to develop an approach that does not leave vacant the terrain of socially organised practices. On the contrary, the whole theoretical approach of the technological field has been developed to provide answers to the questions of how and why these specific practices that led to specific types of craft and ultimately specific types of innovation emerged in the first place. Silverman (1998) seemed to adhere to the principle that subjectivist meanings are founded upon practical knowledge, but this argument does not sufficiently explain the emergence of practices, as I have already explained in the previous chapters. Even Latour and Woolgar (1986) who were less sure about the prevalence of practices, tended to regard them as equally important to the views of the agents. However, the practical knowledge

of the agents can be traced back to the ways they learned and developed subjective interpretations of the technological artefacts that they had to use regularly. By asking the appropriate questions, I will be able to understand how their radical creativity managed to perform a series of personal innovations that in the end resulted in their practical knowledge and their socially organised practices.

Having answered the first question it is now time to clarify if ethnography would be useful to my research. Yes and no. It is true that ethnographic methods could be really helpful as a complementary source of data. Using ethnographic methods I would be able to describe in much more detail the everyday life of specific agents within the technological field. However, there is an important disadvantage which would reduce the quality of my observations and hence the quality of my data. It is impossible via participant observation to uncover ex-nihilo creation within the radical creativity of the agents. Naturally occurring speech is less likely than an interview to result in a narration on behalf of the agents of the way they create ideas ex-nihilo. Observation of the ways they work can be easily misleading because it may confuse the generation of new ideas with the simple accomplishment of specific routines. The conclusions of the analysis of the data from the observation might be a projection of *my own* views about how the radical creativity of the agents in the field really works. The latter problem is common

within ethnography since ethnographic research has sometimes been found prone to resembling the style of the literature preferred by the agents (Atkinson and Hammersley, 1994).

The final category of research method that I considered for my project is the various types of documentary research. Documentary research (May, 2011), which is based on the examination of statistical data or archives, suffers from a severe deficiency regarding the understanding of radical creativity. It is definitely not a direct representation of the views and thoughts of the human agents involved in a social phenomenon. In most cases, the views of the agents, to the extent that they are represented within a document have been filtered by the institutions to which they relate. Hence, the researcher is unable to witness the pure function of their radical creativities. Instead, as Tim May argues, what she or he sees is an ‘institutionalised’ account of their behaviour which depends on the interests of the institution that produces the data/archive within a given socio-technical environment:

“Thus, what people decide to record, to leave in or take out, is itself informed by decisions which relate to the social, political and economic environment of which they are a part. History, like all social and natural sciences, is amenable to manipulation and selective influence. In undertaking documentary research, we should be aware of these influences and not assume that documents are simply neutral artefacts from the past.” (May, 2011, p. 215)

However, even if the documents utilised for the research are not filtered and modified via the intervention of an institution, as is the case for example in an archive consisting of personal diaries, again it is highly unlikely to find inside such documents accounts that describe how the agents' radical creativity functions and how they combine what they create with what they recreate.

Certainly, here, there is the objection that this deficiency is not important and that it is the institutions and their function that matter to the development of the understandings of social phenomena. Indeed, the institutionalised view of 'official' documents could be used as the way to gather some preliminary information regarding a socio-technical phenomenon and, hence, get a brief static glimpse of the institutions of the sector. However, if the researchers reduce their research to the study of documents when investigating technological change, then they have fallen inside the trap of regarding technology strictly as a resource, i.e. in an ensemblist-identitary rationale. The reason is that documents cannot reveal the details of the differences of the approaches of the various people involved in a technological innovation to their object of work, i.e. how their radical creativity functions. Missing these differences however, means that researchers are missing an opportunity to understand how specific types of craft affected a technological artefact and that signals that the understanding of this phenomenon remains incomplete. Hence,

documentary research should be reduced to the preliminary stages of investigating technological innovation.

Thus, I concluded that, even though it suffered from some limitations, the most appropriate method was the conduction of a number of semi-structured interviews. There was always the issue that the interviewees would refrain from presenting the way they think when they want to come up with an idea, but through careful design I have attempted to ask a wide range of questions which capture how agents work. The next sections of this chapter will proceed from the abstract to the specific, i.e. from the general discussion of epistemological and methodological issues to the presentation of the ways my specific research about the field of marine energy technology unfolded.

4.3 Research Strategy

The investigation of the technological field of marine energy technology was performed in two stages. The first stage consisted of a short period of background documentary (mainly online) research designed to produce the static image of the field, as discussed in the epistemological and methodological sections of this chapter. The data from this documentary research informed the second and most important part of the research: the qualitative interviews. The data from the first

stage of the research provided information that I used in the discussion with the interviewees to have a meaningful interview that would reveal their radical creativity. Hence, the final sections of this chapter will deal with a brief description of my documentary research, a presentation and analysis of the questions used in the interviews and how I developed them, a description of the sampling methods and the process of gaining access, a first acquaintance with the interviewees as well as a description of the data analysis and ethical issues of this research.

4.3.1 A Brief Description of the First Stage of the Research

My first confrontation with marine energy technology occurred through the internet. While I was looking for an innovative technological sector in Scotland during the latter half of my first year as a PhD student I first encountered online the terms ‘tidal’ and ‘wave power’ in an article of the Sunday Times (Fraser, 2011). I found out that Scotland was trying to develop an innovative energy system by developing its marine resources such as offshore wind, wave and tidal power. A number of innovating firms and institutions such as Pelamis and the European Marine Energy Centre (EMEC, 2014) were actively trying to construct and install innovative devices in the waters of North Scotland such as in the Pentland Firth.

After some further online research I decided that this sector concentrated a number of advantages that would reduce the complexity of this research. A key source of information was the Scottish government which contained an extensive description of the sector and the government's intervention therein (Scottish Government, 2014b). Firstly, it was a sector which due to environmental factors obliged firms to be based in approximately the same geographical area. Hence, contacting a large number of them was easier. Scotland is a distinct area in terms of the independent dimension of socio-technical reality. Secondly, Scotland was distinct even in terms of the performed dimension. Its institutional complex was different due to its distinct history whereas its natural resources rendered it a unique case in Europe in terms of its marine energy potential. Thirdly, energy generation was a technology which was on the one hand, too difficult to work with unless one had a degree in engineering and, on the other hand, easy enough to understand approximately how its energy generating devices worked.

After reaching these conclusions, I decided to take the next step in my research and seek sources of information other than the internet. To do that, I visited the All-Energy Conference in Aberdeen on May 2011. The All-Energy Conference is the largest in the UK annual gathering of many energy generating firms from UK and overseas (Reed Exhibitions, 2011). The Conference was an ideal location to meet agents

of many different positions in the field. It was possible to meet people who worked in the statutory institutions which had been set up by the Scottish Government to help the development of the sector, members of the developer firms of energy generating devices, members of consultancy institutions and many other diverse agents of the sector (Reed Exhibitions, 2011). In the conference I managed to collect a large number of brochures and pamphlets that the institutions distributed to advertise their work.

After my visit to the All-Energy Conference, I decided that I had enough data to start developing specific questions which would not seem naïve to the interviewees. Hence, I was capable of starting the second and main stage of my research, i.e. conducting qualitative interviews.

4.3.2 Developing the Questions

After the background research, I developed an interview guide (Fielding and Thomas, 2008) with four categories of questions. The first category consisted of the introductory/descriptive questions, the purpose of which was to warm-up, establish rapport and gather information about the interviewee (May, 2011). They were used to make the following questions more specific and helped me locate the interviewees and the institutions in which they worked within the field. The answers to these

questions allowed me to locate them using an enriched personal account and not a sterile bureaucratic description found on a document. The second category consisted of questions designed to provoke a response which would provide information about the ways in which the interviewees innovated, whether that meant having a new idea or developing a strategy or a project. This type of question aimed to obtain accounts of how the agent's radical creativity functioned. The third category included questions which dealt with the handling of innovative ideas within the field, i.e. with the organisation of the field and how it determined the steps that an innovative idea would have to follow to reach commercialisation. These questions were intended to provide data for understanding both the internal organisation of institutions and the interactions among them. Finally, the fourth category included some open questions, the intention of which was to give the interviewee the opportunity to say anything else that had not so far been covered or which could not have been anticipated in preparing the questions.

However, after my first two interviews, I realised that I should not limit myself to the questions that I had prepared and that I had to use a lot of probes and prompts (Robson, 2011) whenever the interviewees left a comment incomplete or I wanted some clarifications. After these first interviews I prepared specific probes for each of my questions which I would address to the interviewee. Furthermore, after my third

interview I found out that I had to add a fifth category of questions to my interview guide. It was a category designed to reveal the power relations between different and similar institutions within the field of marine energy and their impact on the technological paths that marine energy devices would follow. The interview guide can be found in the Appendix at the end of this thesis.

Finally, I have to point out two things. Firstly, this categorisation of the questions does not imply that the data provided by the answers to the questions of each category solely belonged to this category. The data from the answers overlapped. Secondly, since more informed interviewees about the topic of the interview are less likely to forget to mention something important about their experiences in the field of marine energy technology, as has been argued in the methodology, I decided to send the interview guide in advance to the interviewees by e-mail.

4.3.3 Sampling and Access

The questions would be worth nothing had I not decided where to address them. Hence, I will now describe the sampling method. I chose to combine the methods of theoretical targeted sampling (Hodkinson, 2008) with snowball sampling (Sturgis, 2008). During the first step of

my research, i.e. the documentary research, I managed to obtain some basic knowledge of the specific technological sector, including information about potential types of interviewees and topics that I would have to discuss with them. Based on this information, I was able to target specific types of interviewees and then use them as gate-keepers (Bulmer, 2008) who then led to more interviewees with a similar role in their sector as their own.

My ideal theoretical sample consisted of interviewees from all the key types of institutions which seemed to participate in the technological field of marine energy, such as developer firms, investors, statutory institutions and members of the periphery of the field. To avoid biases which would be due to the fact that my sample was a homogeneous group of people and, hence, would then fail to reveal specific issues about the power relations within the field, I decided to try and find interviewees who belonged to different age, sex, nationality and employment. The only thing they had in common was that they participated directly or indirectly in the production of innovating devices of marine energy. Nevertheless, to check the hypothesis that the views of people in similar positions of the field have more things in common than the views of people in completely different positions, I tried to find some interviewees who occupied similar positions in the field.

Gaining access was quite difficult. Initially, I tried to make some

contacts and to arrange some interviews during my visit to the All-Energy Conference in Aberdeen. However, even though they initially stated that they were interested, they did not respond to any of my e-mails. And neither did all the members of the faculty of engineering departments of universities and the employees of developer firms that I contacted via e-mail. Since I had started the efforts to find interviewees in May 2011, by October of the same year, I was at a dead end.

Fortunately, I am a PhD student at the University of Edinburgh. Hence, as soon as I found out that the 'bureaucratic' methods of sending e-mails and going to conferences did not work, I decided to revert to the method of snowball sampling (Sturgis, 2008) and ask my friends and fellow students if they knew anyone who was active in the sector of marine energy technology. A friend served as my first gate-keeper because he knew a PhD student in the engineering department. Thanks to his help I gained access to the students of the engineering department who were actually developing marine energy innovative devices. My two first interviews were with students within the department. My second gate keeper was a fellow student who fortunately knew a leading member of a small developer firm. She introduced me to him and hence I managed to interview members of a developer firm.

The only category of interviewees that I managed to access easily was the members of the public sector. Due to the student-friendly attitude

of the Scottish Government, I managed to interview easily many employees of the public sector and even people that were in quite high positions. On the other hand, in the private sector, only one in five potential interviewees would respond to my e-mail and only one in ten of those responses were positive. Fortunately, after sending a vast number of messages to e-mail addresses which I found usually online, I managed to receive responses and hence, I had the opportunity to interview some members of developer firms and investors consortia. Finally, with the help of my supervisors, I managed to interview some members of the staff of university engineering departments. The latter category of agents of the field of marine energy proved to be very hesitant to arrange an interview. Not even one member of an engineering department accepted to arrange an interview before the intervention of my supervisors, even though I repeatedly contacted them.

Some of the interviewees insisted that they had only a limited amount of time available for the interview. Several insisted that it would not be possible to meet me in person and that we would have to do the interview over the phone. Since telephone interviews tended to be shorter, this was a severe constrain on my capacity to obtain rich information about their work within the field (Bryman, 2012). Over the phone it was more difficult to build rapport with the interviewee because enhanced communication skills were needed (Fielding and Thomas,

2008) which I did not possess in abundance especially due to the fact that I was not a native speaker of English. In addition, telephone interviews hindered me from using body language (e.g. a smile and a firm and friendly handshake) to build this rapport.

4.3.4 The Interviewees

By the end of my fieldwork, I had managed to interview people who were active in diverse positions within the technological field, as well as some who occupied more similar positions. Hence, my sample of interviewees was very close to my ideal theoretical sample. To be more precise, I managed to conduct 25 interviews, most of them in person and some by the phone. The material gathered is approximately 13 hours long. I divided the 25 interviewees into the following categories:

1. The developers

The interviewees worked in firms or consortia which were developing innovative marine (wave or tidal) energy devices. They were responsible for transforming a device from an invention to a commercially successful machine ready for installation. Their role was the most critical within the field of marine energy, because without them, the field would be non-existent. However, this category involved a wide range of distinct institutions in terms of size, from small firms with a

handful of personnel to large consortia composed by international corporations and agencies of the public sector. I interviewed four developers and they included a leading member of a small developer and constructing firm, one of the leading members of a large consortium of investors and developers, and two members of a small developer firm involved in a community led project.

2. The academic researchers

Their main contribution to the field is the initial invention of innovative types of devices. This category included members of university staff and PhD students who usually seek funding from the private and the public sector to transform their projects from ideas to prototype devices. This category included seven interviewees who all worked in Scotland. To be more precise, a Spanish and a Turkish marine energy engineering PhD student, a Greek and a Canadian PhD student in other sectors of renewable energy engineering (wind energy and Biochar respectively) and three members of university staff, a marine energy policy research associate, a marine energy engineering research associate and a renewable energy policy research fellow.

3. Public sector workers

Usually, the work of staff in this sector is to regulate the field, i.e. to make sure that the other institutions of the field of marine energy abide by the laws and regulations of the UK. A second function is to

perform an institutional innovation, i.e. to contribute to the development of regulation and/or advice in domains which were non-existent before the emergence of the field of marine energy (e.g. to the development of the rules for the environmentally friendly installation of marine energy devices in UK's seas). I interviewed seven people. Among them there were members of the statutory institutions which are responsible for the regulation of specific renewable energy resources, members of public institutions responsible for the protection of the environment, members of local authorities and politicians.

4. The members of testing facilities

Their role is to facilitate the development of marine energy devices by providing a prepared area for testing the devices and therefore allowing for a reduction of the cost of this work. Since the development of any technological sector is heavily depended on cost-efficiency, their contribution to the field is of extreme importance. There are only a small number of such institutions in the UK and fortunately, I managed to interview two people from this category, one leading member of a testing facility which is important at the earlier stages of the development of a marine energy device and one member of a facility which is of extreme importance in the later stages of an innovative project.

5. The members of the periphery of the field

They provide a wide range of services to the institutions of the

'core' of the field, including consultancy, provision of various products necessary for the construction of marine energy devices, construction and port facilities. Finding interviewees from this category was difficult, but fortunately I collected five interviews from agents of the field with very different peripheral tasks. The interviewees of this category include one member of a consortium of universities who works as a networking agent between the academia and the private sector, a member of a distribution company, a leading member of a construction and repair firm, a leading member of a firm which produces and provides marine measurement instruments and a leading member of a consultancy firm.

Having described the ways I conducted my data collection, the next section is dedicated to the description of how I analysed the data.

4.3.5 Data Analysis

Data analysis was completed in two phases. The first phase consisted of the analysis of the data generated from the documentary research. As has already been mentioned, this type of data can provide only a glimpse of the most recent past condition of the ever-changing technological field. Therefore, the target of the analysis was the extraction of as much information as possible which could be suitable for the formation of the five types of questions presented in the previous

sections.

The second phase consisted of the analysis of the technological field as it was during the time-frame of the interviews. Here, data analysis attempted to generate a theory, i.e. to provide an image of the regulation of the field of marine energy in Scotland and its effects on the speed and orientation of technological change. Although it is true that technological fields can change in a discontinuous way, this fact does not mean that they are entirely unregulated (actually this was the reason why it made sense to talk about a field in the first place). Therefore, the image derived from the interviews can be used as policy advice if it would manage to approach the personal character of the agents' behaviour. To achieve that, the data from the interviews required an innovative mode of analysis capable of capturing both the internal regulation of the field and the idiosyncratic character of each response. This analysis consisted of the following steps.

The first step was the application of an open coding method which would attempt to identify the issues, beliefs and ideas revealed by the interviewees during each interview. Here there was no hierarchical manipulation of the concepts derived, e.g. there was no characterisation of some beliefs as subordinate or special cases of others. What I tried to do was to identify the elements in the perspective of their radical creativity, i.e. the beliefs, ideas and hypotheses the agents revealed

during our conversation about themselves and the field. The reason for the absence of a hierarchical categorisation of the various elements of the radical creativity of agents was because I could have confused a hierarchical classification that belonged to my own radical creativity with the hierarchical classifications that the interviewees actually did. There was no reason why an interviewee should obligatorily adhere to a hierarchical categorisation made by the researcher. It was therefore better to avoid such categorisations and to simply identify issues, beliefs and ideas revealed by the agents.

Nevertheless, this analysis was not reduced to a simple identification of the elements of radical creativity. The second step was the classification of the data according to how similar or divergent they were. The answers to each question were scrutinised and patterns of convergence and divergence were identified in the responses of the various agents. The responses and the concepts therein were categorised into groups according to the points of convergence and divergence. Similarities in the answers of agents could imply that there were similarities in the perspective of their radical creativity. These similarities in turn could be due to the internal regulation of the technological field. The reason for the classification according to points of divergence was the fact that the technological field is a framework which attempts to investigate changes. And change is the creation and

appreciation of differences. Differences within the field were as valuable as similarities for the understanding of the behaviour of agents in the field, especially their innovative behaviour. It was the first way to trace the effects of radical creativity.

The third step was to trace the radical creativity as the interviewees narrated its function. The purpose of this step was to uncover how the interviewees worked to develop a new idea. That way, it was possible to find out how the agents described the use of the perspective of their radical creativity when they created ex-nihilo. Again I identified similarities and differences for the exact same reason that I explained in the previous paragraph. This is research that did not search only for similarity patterns but instead tried to understand why the function of the radical creativity of each agent for example differed.

The fourth step was the positioning of the answers in a network which demonstrated points of convergence and points of divergence within the results of the second step and those of the third step. The details of the regulation of the technological field of marine energy in Scotland and the modes of change within, according to the views of the agents within it, were a derivation of the analysis of this network.

4.3.6 Ethical Issues

I decided not to cite the full names of my interviewees because I chose to follow a policy of strict anonymity and confidentiality in my research. All the interviewees were informed by e-mail about the aims of the research, which were to help me complete this scientific project, and they were asked to send me their consent for the realisation of the interview by e-mail, only after they had received a full list of the questions. Each interviewee had the option not to answer any of the questions. Those who did choose not to respond to some of the questions were the leading members of statutory institutions. The reason was that they could not reveal specific criteria about the decision making process in their agencies in order to avoid revealing confidential information to the institutions that they regulated.

Furthermore, each interviewee received a copy of the transcript from the interview and had the right and the opportunity to opt out from any part of the answers he or she would choose, but nobody did. There are no moral issues or conflicts of interest because I did not and do not participate in the firms, agencies and departments where my interviewees work. All names and identifying information about their interviewees and their organisations have been removed. No potential physical or psychological harm, discomfort or stress was caused by this research. There is no aspect of the proposed research which might bring the University into disrepute. There were no vulnerable participants in the

research since everybody was an adult and the questions were not designed to invoke anything that would be stressful to the interviewees. In addition, during the interview nobody complained about feeling any type of discomfort.

4.4. Summary

This chapter has discussed the epistemological and methodological premises of my approach. The technological field supports a subjectivist epistemology with some objectivist elements which exist due to the interdependence of the agents within the field and the impact of the independent dimension. Following this rationale, I chose to use qualitative interviews. This method is a great way to get a close view at the interviewee's radical creativity. Before the interviews, I conducted a brief investigation of the sector of Scottish marine energy in order to produce some data that would inform my questions. Furthermore, I have described the main categories of the research questions that I addressed to the interviewees, the sampling methods and the process of gaining access. Finally, I briefly described the categorisation of the interviewees into groups within which they share a more or less similar radical creativity.

I will now move to the main empirical part of the research and

address the anthropological and institutional questions. The next chapter's target will be to present the first step of this research, i.e. the description of the static image of the field of marine energy technology produced after the documentary research.

Chapter 5: Setting the Scene

What follows is a very brief description of the results of the first stage of my research, i.e. of the preliminary documentary research. The static image of the technological field that it produced is the start of the answer to questions three and four of this thesis, i.e. the anthropological and the institutional questions.

Marine energy is the energy derived from the motion of the waves and tides and hence, it is divided in two types: wave energy and tidal energy. The source of this energy is a qualitative characteristic of this type of energy which is related to the independent dimension and justifies the existence of a separate technological field for its extraction. To extract it, it is necessary to build a device in the ocean, capable of turning the motion of the waves or tides into a circular motion of some type of instrument within the machine. This circular motion is a common feature of marine energy and wind energy, and this is why marine energy can be considered a subfield of the field of renewable energy. However, the complexity of the environment of the ocean is much higher than with other types of energy. This is the reason why until recently there were no commercial tidal energy devices and commercial wave energy devices have not been developed yet. This complexity is particularly apparent in the extremely high installation costs of these devices. To consume

marine energy, the energy that the devices generate has to be transported by the national grid. Hence, marine energy technology has a lot in common with two separate sectors: wind energy technology and the various types of marine engineering.

In the UK and particularly in Scotland, the Scottish Government aims to exploit marine energy technology as one of the components of a major technological change, a technological transition. According to the Climate Change Scotland Act (2009), the Scottish government has set a very ambitious target for future energy use in Scotland. Greenhouse gas emissions will have to be reduced by 42% by 2020 and by 80% by 2050. Beyond the plans for the future, Scottish authorities have, during the last 10 years, managed to increase significantly the generation of energy from renewables beyond hydroelectric methods. On-shore, off-shore wind (mainly) and marine energy contributed only 306 GWh (0,6% of production) on 2000. In 2009 these renewables contributed to Scotland's energy production with 5868 GWh, i.e. 11,9% of the total amount of energy production in the country (Department for Energy and Climate Change, 2010). Such a major change, from an economy based on hydrocarbons to an economy that relies on 'clean' energy sources, such as the wind and the waves, is a major technological innovation. An innovation of this scale will be completed only if several smaller technological and institutional changes are made within Scottish society.

During this investigation Scotland formed part of the United Kingdom, a state with one of the most globalised economies on the planet. The Scottish economy formed part of this globalised free market economy. However, it made sense to study it as a distinct case, because it was institutionally distinct from the rest of the UK. It was a semi-autonomous area with its own government and legal system. In spite of its inability to regulate taxation within Scotland (Scottish Government, 2011), the Scottish government was capable of taking important decisions regarding the future development of the country.

In addition, Scotland possesses resources that cannot be found in the rest of the UK. For example, Scotland possesses 25% of Europe's tidal power and 10% of its wave power (Forum for Renewable Energy Development in Scotland – Marine Energy Group, 2009). These resources rendered Scottish prospects for development in the sector of marine energy unparalleled with any other area in Europe, especially when considering the special measures that the Scottish government had put in place to make sure that Scotland could adequately exploit its marine energy potential. For example, the Scottish government was particularly interested in the development of the Pentland Firth, where EMEC, i.e. the European Marine Energy Centre, was already involved in the testing of innovative technologies (Marine Scotland et al., 2011). The Scottish Government also had policies to drive marine energy forward,

such as the Saltire prize and the Renewables Action Plan, discussed below.

The Saltire prize was an international competition related to the construction of a commercially viable means to extract electricity from the power of the sea. To win, a firm would have to be able to generate 100GWh of electricity by July 2017. The winner would be awarded ten million pounds. The prize was intended to guarantee that the developing firms of the field would stretch their limits and increase the pace of their innovative work, lured by the large award (Scottish Development International, 2011). The Renewables Action Plan (RAP thereafter) was, as its name suggested, a plan for how the Scottish Government would achieve the targets mentioned above. The RAP described how the Scottish government would coordinate the actions of various public and private institutions related to the field so that the change towards renewables would be fast and both the generation and the supply of electricity guaranteed (Scottish Government, 2009).

Moving beyond the contribution of the state to the field, in the UK, marine energy devices as a whole were constructed by marine energy developer firms, as Mueller and Wallace explained:

“Since the end of the 1990s there has been significant growth in marine technology developers, with some successful prototype deployments in European waters, such as Wavedragon, Pelamis by Ocean Power Delivery,

Archimedes Wave Swing by Teamworks Technologies, Seaflow by Marine Current Turbines and Stingray by the Engineering Business.” (Mueller and Wallace, 2006, p.36)

In Scotland these were privately owned firms and they demonstrated a wide diversity in terms of size and budget. They varied from very small businesses with a handful of employees (e.g. see Nova Innovation Ltd., 2014) to subsidiary companies of huge corporations like Siemens (e.g. see Marine Current Turbines Ltd., 2014). As a whole, the birthplace of a marine energy device in the UK was usually the developer firm (Mueller and Wallace, 2008). However, each device contained a number of different types of artefacts which were neither invented nor commercialised necessarily for the first time by the developer firm. They were either nearly identical to technologies already used in the wind energy sector or in other marine activities such as the oil and gas industry or they were new technologies that had been initially developed in the engineering departments of universities such as the University of Edinburgh (e.g. see University of Edinburgh, School of Engineering, 2014).

Research in university engineering departments was conducted by academic staff who exercised little control over the specific goals of the research. The aims of the research were, instead, decided by those institutions which provided funding, such as the Engineering and Physical Sciences Research Council (EPSRC). These institutions were

usually either privately owned companies or attached to the Scottish Government. Senior members of staff mostly conditioned and particularised the research which was conducted either by themselves or by research associates and PhD students, according to the dictates of the funders. To maximise the impact of the research and to speed up the development of renewable energy technologies, including marine energy, UK's universities formed consortia such as the UKERC (UK Energy Research Centre, 2014). Furthermore, since the commercialisation of the products of the research required the collaboration of researchers and developers, Scottish universities also formed consortia, such as the Energy Technology Partnership (ETP) and hired people with this exact purpose, i.e. to promote their research and achieve the linking with various types of developer firms.

After a marine energy device was developed, it was then necessary to install it in the water. However, the huge installation costs of devices rendered the immediate installation of a new unproven technology particularly risky (Carbon Trust, 2011). Testing was necessary before any further step was taken. This was the service provided by testing facilities some of which allowed for the testing of miniature devices in a testing tank on dry land in a controlled environment whilst others gave the opportunity to test the device in the ocean and particularly, in the Orkney Islands (Elliot, 2010).

After the testing stage, the device was supposedly ready to be installed. However, installation costs a significant amount of money and, hence, developer firms needed to find investment for their projects. There were many types of investors, from consortia of huge corporations (e.g. see Energy Technologies Institute LLP., 2014), to government agencies and small communities. The latter are especially important for the smaller types of devices which were designed to provide energy only for local communities and not to the national grid (e.g. see Community Energy Scotland, 2013).

Even after finding someone to invest in it, the device could not be installed without the permission of governmental agencies like Marine Scotland and Scottish Natural Heritage (SNH). These agencies had a constraining and enabling effect on the field. On the one hand they constrained the developers by obligating them to adhere to some rules for the correct management of the sea and the balancing of various different activities in the ocean. On the other hand they enabled the developers to produce more efficient devices by conducting research and gathering data regarding the conditions of the marine environment. Once the device had been approved to be installed by SNH and Marine Scotland, the developer took a specific lease for an area within Scottish waters in which they could then install the device (Scottish Government, 2014c).

During this whole process, the developer required a number of services not provided by themselves or the government. These services included everything from the use of specific marine instruments to the distribution of some types of artefacts and to the acquisition of advice from consultancy firms (e.g., see SgurrEnergy Ltd., 2012). These were the institutions that comprised the periphery of the technological field.

This completed the analysis of the first step of this research. Marine energy is a type of energy with its own qualitative characteristics which are related to the independent dimension and, to be more specific, the complex character of the oceanic environment. Based on these qualitative characteristics, a technological field has emerged which is a subfield of the field of renewable energy and consists of a number of specialised public and private institutions. These institutions are either innovations themselves (for example, the testing facilities) or include innovations (such as specialised PhD programmes) and engage in relations of competition and cooperation in order to deal with the idiosyncratic characteristics of marine energy. Finally, Scotland is an ideal place to study innovation in marine energy technology since it is a place with abundant marine energy resources. All these characteristics of the sector of marine energy technology in Scotland render it an ideal case study for the approach of the technological field.

On the other hand, the previous analysis provided information

mostly about question four, i.e. the institutional question of this thesis and much less about question three, i.e. the anthropological question. This is not surprising, since the institutionalised view produced from the documents of the technological field was unable to describe the characteristics of the innovative activities of the agents of the field. Such a description was possible only after the analysis of the data from the second stage of the research, i.e. the interviews.

Chapter 6: Radical Creativity – The Perspective

The purpose of this chapter is to answer the anthropological question of this thesis, i.e. to understand how the agents of the field interact with technology. However, before proceeding with this task, I have to explain the implications of conducting research according to the suggestions of the theory of the technological field. As Bourdieu (1989) put it any theory imposes a vision of divisions of socio-technical reality and obliges researchers to study their objects of research in very specific ways. Hence, I have to briefly explain what the theory of the technological field suggested that I should search in the data from the interviews.

The theory suggests that, to understand the interactions of the agents of the field with technological artefacts, it is necessary to develop an understanding of their radical creativity. The latter consists of two parts: the perspective and the capability to create *ex-nihilo*. This chapter will deal with the first aspect of radical creativity, i.e. the perspectives of the agents of the field. *Ex-nihilo* creation will be the topic of the next chapter which will complete the answer to the anthropological question.

The perspective is a creation and at the same time, a sophisticated reflexive internalising method of sets of behavioural patterns. The internalisation takes place through the experiences the agents have in

their lives: firstly via learning and secondly via performing a large number of minute personal innovations which most of the time are not even noticed but they allow humans to deal with the complexity of everyday life. Since, in the case of this research, all agents are active in a technological field and interact with technological entities, the theory of the technological field suggests that the experiences of the agents should influence to a certain extent their interactions with these technological entities. To be more specific, the experiences of the agents have offered them the opportunity to internalise guidance about how to behave in any potential situation in the technological field. These instructing sets of behavioural patterns include the necessary directions for the accomplishment of the tasks of each position in the field. Agents with more similar positions in the field should have more similar perspectives because they share a large number of experiences in the field.

The second suggestion of the theory is that, since the internalisation process is reflexive, the interviewees should be able to narrate the way they adapted to the 'life' within specific institutions. This 'life' consists of experiences of interacting with elements of both the performed and the independent dimension of the technological field. To participate in the function of any institution, the agents of the field have to adopt some sets of behavioural patterns which help them deal with the challenges these two dimensions pose.

In the following sections, I present the results of the analysis of the data from the interviews according to the suggestions of my theoretical approach. Section 6.1 describes the main characteristics of the perspectives of the agents of the field of marine energy technology which include the influence of their early age experiences, their values and their personal incentives for pursuing their careers in the field. Section 6.2 presents how the interviewees narrated the way they adapted to life in the technological field and how they developed specific sets of behavioural patterns to deal with the elements of the independent and the performed dimension of the field.

6.1 Building a Perspective

6.1.1 Past Experiences

The most common characteristic of the perspectives of the interviewees was the importance of their past experiences, and especially those obtained at an early age. The interviewees not only remembered the reasons why they worked in their respective positions but were also able to describe the impact of their early age experiences on their career choices. A large number of interviewees declared that the formation of their career choices started at a very early age, their childhood or

adolescence. Most of these choices were the result of experiences they had in their educational or familial environment. Such answers are given by all the categories of interviewees, i.e. from interviewees as distinct as PhD students, leading members of public institutions, leading members of firms from the periphery of the field, leading members of testing facilities, members of developer firms and politicians. These agents of the field of renewable/marine energy had developed interests and skills, i.e. sets of behavioural patterns relevant to this field at an early age.

However these sets of behavioural patterns did not develop in an identical way for all the interviewees. There was diversity in the factors which proved to be more critical to the career choices of the interviewees. For example, in the following extract, a leading member of a testing facility who started his career as a mechanical engineer revealed that the most impactful to his career early age experience was the experience of piecing together and taking apart his bicycle:

“At the very start I used to take my bicycle to pieces. And it was really just that background. I used to help my dad fix the car. Mostly I was the young boy pumping the gas pedal while my dad was cleaning the brakes, that kind of thing. My dad's an engineer on the electrical side. I couldn't get my head around electrical engineering and mechanical engineering was the natural position for me.”

To other agents of the field, such as a leading member of a consultancy firm, one of the critical factors for his career choices was the experience of living close to the sea. Moreover, to a leading member of a statutory research institution, school experiences were exceptionally important, as can be seen in the following quote:

“So, and then I was interested in things sort of environmental and had some introduction to geology as part of some school...We did some geology physical survey work on Skye when I was in the 6th grade during my summer holiday... And there was an opportunity to take geology in the first year in Cambridge in addition to more standard things as maths and chemistry stuff. And I enjoyed it and I decided to stick with it.”

Hence, the answers of the interviewees point to the fact that there was a multiplicity of early age experiences that affected the interviewees. The interviewees mentioned a significant number of diverse and distinct stimuli that led to specific career choices.

This finding is congruent with the theory's suggestion that the interviewees could internalise their experiences in different ways, because human behaviour is complex and it is not possible to entirely describe its determination by specific types of experiences. The interviewees were influenced by the elements of the independent and performed dimensions they encountered during their childhood. Hence, they adopted sets of behavioural patterns which had a large impact on

their future career decisions. However, each interviewee was influenced more by different aspects of the independent and performed dimensions and developed distinct sets of behavioural patterns. For example, in the previous quotes, schooling influenced more the leading member of the statutory institution than the member of the testing facility. Hence, even though it is certain that the interviewees were influenced by early age experiences, it is also correct that each interviewee was influenced by a different set of early age experiences which may or may not be similar to others.

The diversity in the impact of various sets of experiences became even more apparent as soon as I found out that a minority of interviewees discovered their interest in the sector of renewables and engineering not during their infancy or adolescence, but later in their lives. For example, a member of a public regulatory institution first decided to work as a police officer, as can be seen in the following quote:

“I've come here by quite a peculiar route, by quite a different career. So I lived abroad after my school, then I worked for a few years as a police officer. I hadn't decided to go to the University mainly because when I left school it wasn't clear what I wanted to do. So, it was only after a few years I was having my first career that I decided that I wanted to go on and have a chosen degree. But I wasn't certain what I really wanted to do in 2000. So I went to the zoology degree and followed that up with a PhD. The area of research was population dynamics in fishery

communities across Europe. I then decided that I didn't really want to work in academia, I wanted to do something more applied, so that's how I ended up working for [name of institution].”

The interviewee decided her career path much later than her adolescence. Similarly, a leading member of a local council entered the sector of marine energy after studying in the life sciences and working in the commercialisation of research, and a member of a statutory institution changed a number of jobs before settling in the marine energy services of the public sector.

These exceptions to the rule of the primacy of early age experiences show that radical creativity is a flexible ‘instrument’ and that human behaviour is not entirely determined by specific types of experiences. It is true that some agents both learned which options they had in terms of pursuing a career and decided the sector of their preference when they were very young but the answers of the interviewees who chose to change their career later in their life clearly revealed that the impact of these experiences was not irrevocable. Even though human agents are influenced by early age experiences, they are able to adopt new sets of behavioural patterns over the course of time and after a period of many personal innovations to adapt successfully and work in a sector that can be entirely different. Whether or not they will be able to join the new sector of their preference will depend then on

the specific characteristics of the institutions of this sector and, in this case, to the specific features of the technological field. Hence, to understand elements of the perspective of radical creativity of the agents in a technological sector, it is important to take into account their early age and, in general, past experiences without, however, assuming that the impact of these experiences is irrevocable.

6.1.2 Personal Incentives and their Characteristics

The perspective of the interviewees did not include only their past experiences. Another key element of their perspective was their motivations for firstly entering the field and secondly continuing to work there. These motivations were not simply related to their early age experiences, but instead, they had to do with the view they had at a certain point of their lives about their future. I named this type of motivations to enter the field ‘personal incentives’.

The majority of the interviewees, who mentioned a personal incentive, joined and continued working in the field of marine energy technology in order to progress in their careers and obtain personal gains. This is not surprising because these interviewees were members of a late modern society, a society where the rational pursuit of personal gains was both acceptable and widespread (Weber, 1947). However, the

data revealed that there were respondents who did not always associate progress in their careers with financial success, as well as other interviewees who attributed specific qualitative characteristics to what they defined as personal gains. The main types of personal incentive mentioned by the interviewees were the following, each of which was mentioned by up to a third of the interviewees:

1. A personal interest in terms of seizing an (mostly financial) opportunity was mentioned by the majority of interviewees.
2. The tangibility of the results of their work.
3. The pursuit of challenges and diversity to escape boredom.

The first and most important and commonly cited personal incentive was the seizure of an opportunity to enhance one's well-being. Eight out of 25 interviewees, and especially those who hold key positions for the completion and commercialisation of an innovation (for example, leading members of constructing, developing and consultancy firms and important public sector employees), claimed that they had joined the sector because they wanted to seize an opportunity to progress in their careers. This justifies Weber's (1947) argument that modern agents frequently choose their actions not according to their adherence to specific beliefs but according to their personal and rationally evaluated interests. The fact that this incentive was cited by agents, who had the potential to reach such positions in the hierarchy of private and public

institutions in the sector of marine energy, means that they must have felt able to find valuable opportunities in the marine energy field.

However the most interesting conclusion derived from the data had to do with the way the interviewees sought and defined their personal interest. The agents of the field tried to use their past experience in other sectors as their competitive advantage in the field and were less risk-averse than the agents of other, more established fields. For example, as can be seen in the following quote, the leading member of a small construction and developer firm who chose to join the marine energy technology sector considered his background in the subsea construction sector a valuable tool for his career in the marine energy sector:

“I moved into marine energy, because obviously due to my background in subsea construction it seems like a logical place to go. One of the reasons also is that it's a very new industry and there aren't lots of people in it. So, it's an opportunity to get in there and into something new.”

The respondent claimed that in the case of marine energy, the experience of working in the sub-sea construction sector could help someone join the marine energy sector. Working in the sub-sea construction offered the opportunity to obtain specific sets of behavioural patterns which would be useful to the relevant sector of marine energy technology. In addition, the interviewee revealed that there was only a limited amount of people working at the start of the development of a field of a new technology,

and, hence, there was enough 'space' for people from other sectors to come and exploit the available opportunities.

This type of opportunity was related to the 'newness' of the sector. A new sector with few personnel needed the entrance of people who had gained entrepreneurial and engineering experience in other sectors and were looking for a new opportunity. This experience was much more valued in the new sector than in the already established ones, as can be seen in the following quote from a leading member of a testing facility:

“Because my entrepreneurial kind of period was quite so far away from engineering, if I came back here to work, I had to probably come back in at something where it is fairly new and I was at age 40-something... So that's kind of why I decided to stick with engineering and specifically renewable energy engineering, because it's a very young and growing industry and I figured that my age and seniority and entrepreneurial skills would help work at the plain field with people having very recent engineering qualifications.”

The respondent revealed that, at the age of 40, he could pursue a better career in a new and innovative engineering sector, because his past experiences as an entrepreneur did not occur in an engineering sector. His seniority and entrepreneurial skills, i.e. the sets of behavioural patterns he had obtained during the years of his experience would be useful to a sector where people had very recent engineering

qualifications. He intended to use them in order to have a new and better career since the sector of marine energy technology valued more these sets of behavioural patterns than other more established sectors. This is a key qualitative characteristic of the sector and the perspective of the agents who decided to work there and highlights the way the interviewees defined their personal interests.

Even so, the problem faced by the interviewees who wanted to exploit their sets of behavioural patterns, was that the lack of personnel in the sector went hand in hand with a lack of financial investment. There were interviewees who argued that other, more established sectors, received more funding and, hence, could offer more employment and higher wages. This difference in terms of funding between established and non-established sectors, such as the sector of marine energy technology, was obvious in the following extract from the interview of a PhD student:

“There is a lack of funding because there is a lot of uncertainty in the technology. So, nobody wants to put his money there, because there is no proven technology currently. So, if I am an investor and I have like eight million pounds and I want to make more money, I would prefer to make an investment in onshore wind energy which is a proven technology rather than go for something that it could be good, but there is just still nothing out there.”

Sectors of proven technologies, which had already been commercialised such as onshore wind energy, received more funding than sectors of unproven technologies such as marine energy. The existence of funding was described as a prerequisite to the existence of opportunities in a sector.

Examples of this conclusion were the views of the PhD students who confirmed that opportunities for innovative PhDs existed only in topics which were funded by either the private or the public sector. University staff and students conducted research on topics that had already been chosen by others. They were able to choose in general terms the scientific or technological sector in which they worked, but not the exact research topic. An example of the answers they gave, when asked how they had chosen a specific PhD project, was the following:

“Well, to tell you the truth, this project was more or less what I did in my thesis as a master student. So, this was just something I was working on and there was this opportunity from a company who funded such research. So, it was already kind of fixed what I should do for this project.”

The PhD student did not freely choose to do his PhD topic. It was a decision based on an opportunity offered by a firm. This pattern appeared for every PhD student or research associate who was interviewed. Decisions about research were taken via a top-down process. The topics

were first decided by whoever controlled and funded the research, usually by a department or institute within a University, sometimes directly by a firm that funded such research.

The importance of funding was further revealed by the following extract from the interview of a PhD student who claimed that the survivability of new technological fields depended heavily on specific sources of funding, such as the Scottish Government:

“Well, great young scientists are available and I think that they can oversee these challenges. The challenge that we can't overcome, we can't change is that if the government does not support this type of energy and goes for another type of energy. That's what we can't do. If the money is there I think the technology is going to be ready. But if the money is not there, even if you make the brightest students and the brightest scientists, then the funders will leave the sector and go where the money is.”

The respondent argued that funding was a *sine qua non* of the survivability of an innovative sector. Some funding would have to be derived from the public sector exactly because private investment did not suffice. In addition, the sector of marine energy would have to compete with other sectors to convince the government to fund the sector.

If opportunities depended on available funding and funding was more abundant in the established sectors, then the interviewees chose to enter the marine energy technology sector because they were less risk-averse. Innovative sectors contained opportunities to build a career due to

the lack of experienced personnel. On the other hand, established sectors guaranteed that the agents therein would not incur a loss due to the withdrawal of the funders' support from the sector. When deciding which sector to join, the respondents chose the sector with the most opportunities related to their past experience and not the sector with the most secure sources of funding.

The second personal incentive to enter the field of marine energy was the ability to work and produce something that was tangible. Tangible results were considered a desirable characteristic of a type of employment either by respondents who were actively trying to innovate or by those who felt that they belonged to a community and wanted to see that their job made a difference there, as can be seen in the following extract from the interview of a leading member of a small developer firm who explained how proud he was due to the prototype marine energy device they were building in his firm:

“There’s one prototype we are doing at the moment. I’m very proud of that. When I was working at IBM, I was working in manufacturing and I ended up designing, building a listed computer monitor which was quite very different, very innovative at the time and I was very proud when I saw that in the selves of the high street shop... So, I’m proud of that. I think that’s when I realized that I get most enjoyment from actually doing, building something and seeing a project through to the point when I can point and say “I helped do that”. And that’s a very important thing for me. I never ever got that in banking. You can’t

look at a cleared trade and say oh that, that was me, I helped do that. I just don't see it.”

The description of this personal incentive in the answers of those within the field who actively tried to build technological artefacts signified that these people did not experience everything as standing-reserve in the way Heidegger (1954) described it. The object of their work, the artefact that they were constructing was not a mere resource to do something else but rather a new reality with its own value. To the member of the developer firm, the value of the innovations he had been constructing was something more than the financial benefit he would receive from their commercialisation. Had he simply desired financial gains, he could have continued working in the financial sector.

The third personal incentive was the need to escape boredom and to find an employment that was intellectually stimulating. It was observed mostly among people who worked in the private sector and were actively involved in innovative activities, as can be seen in the following extract from the interview of a leading member of an innovative testing facility:

“At that point I was bored of being semi-retired and I went on to do an MSc in Renewable Energy engineering at [name of Scottish University]. And that led to a job with a renewable energy consultancy in Glasgow as an expert in renewable energy. I worked there for effectively three years

in their advisory services team which is specifically being their head of the technology assessment team.”

To conduct societal innovations, i.e. to create things that have never been created in the past and to introduce them within socio-technical reality, it was important to feel the need to escape boredom. What that means is that radically creative human agents do not simply derive their ontological security simply from stability, as for example Giddens (1984) argued. Instead the degree and location of stability and change that generates ontological security depends on the radical creativity of each human agent as it has been formed within the technological field. It is exactly for that reason that people who worked in innovating positions in the field seemed to derive some pleasure from the construction of technological innovations, i.e. from a *change*.

6.1.2 Values

Even though upbringing and personal interests are important, they did not tell the whole story. Many interviewees argued that the main motive behind their choice of career had to do with specific values. The analysis of this category provided even more information about the perspectives of the radical creativity of the agents in the field, as well as a glimpse both of the internal organisation of the technological field of

Scotland's marine energy and of the relations between this field and the rest of socio-technical reality. The analysis verified Weber's (1947) view that values were an important motivation of human action. The word values, refers to 'specific moral beliefs to which people appealed for the ultimate rationales of action' (Spates, 1983).

Firstly, the interviewees mentioned frequently environmentalism, i.e. the importance of the protection of the environment and support for sustainable development (Heywood, 2012) as one of their motivations. Environmentalism was not always compatible with the personal interests of the interviewees, but was deemed as critical in their choice of career by PhD students, members of developer firms and members of the public sector. The desire to support the environment was evident in the answers of the interviewees in many different questions about diverse aspects of marine energy production. For example, the leading member of a statutory institution, when asked about the importance of the contribution of his organisation to the sector, responded:

"It's important in the sense that we as an organisation can deliver a greater degree of process which is about planning any modification and consideration of potential sites for development through the planning process, through the licensing process to ultimately, make decisions and recommendations on the issue of consents and licences for the placement of these things at sea and then to deal with the legacy issues that there are any regarding the potential impacts, on the environment with

regard to monitoring conditions, check monitoring approaches providing guidance and help.”

The respondent described dealing with legacy issues and the environment as an important part of his institution’s contribution to the sector and Scottish society in general. Hence, it is one of the things that justify the existence of regulatory institutions in the sector.

A large number of agents who searched employment or worked in the sector of renewable and marine energy shared the view that environmentalism is important. This was obvious because about a quarter of the interviewees included it as one of the values in which they adhered whilst seeking employment or working in the field. However, what was even more interesting was the fact that even if, when entering the field, the agents did not explicitly adhere to this value, this could change. As they participated in the field, it was possible that they would soon acquire a significant part of its ‘resident’ ideology, as evident by this answer of a member of a statutory institution responsible for the regulation of renewable energy:

“When I moved from the health department, it was an opportunity that came around and I just said yeah, it sounds interesting. And since I’ve actually gotten into it, it realised a passion within me that I did not know how to fill, for the marine environment and the need to feel, trying to conserve and then telling what we do have out there... So that my daughter for instance has, has a clear

energy supply that won't actually cause any problems in the future.”

This quote revealed that not only was environmentalism also something that could be learned through the experience of working in a technological field, but that this experience also ‘taught’ the agents of the field the need to care about specific ecosystems such as marine environment. The existence itself of public institutions responsible for the protection of the environment demonstrated that the protection of the environment was one of the values that ‘pervade’ the field and the agents therein to a very large extent. However, this should not give the impression that environmentalism was a value that was created in the field. Instead it was a value that the field received from the rest of the society. This was justified by the presence of elements of environmentalism in the views of two politicians, a Conservative and a Green. If the presence of environmentalist ideals in the ideology of the member of the Green Party was not surprising at all, their presence in the perspective of the member of the Conservative Party revealed that environmentalism had impacted significantly Scottish politics as a whole.

Secondly, the Scottish interviewees highlighted the value of caring for the local community of Orkney and Scotland as one of their prime motivations for participating in the field, as can be seen in the following extract from the interview of a member of a local authority:

“My background was with life sciences and the commercialisation of research for 20 years. The move actually was a personal one. In a way I am of the region, I have my family up here. The opportunity came up and I applied for it, it is as simple as that.”

The respondent revealed that the desire to contribute to specific communities was usually derived by the experience of having lived in those communities and went hand in hand with a sense of belonging to a specific place/community. This value was mentioned by a leading member of a testing facility, a member of a local council and a member of a public regulatory institution.

Thirdly, another value mentioned by two interviewees was anti-militarism. A Turkish PhD student declared that he chose to join the renewable energy sector in order to avoid joining the military sector. Another interviewee argued that he left the defence industry and decided to join the marine energy industry due to the following experience:

“I was working in the defence industry and I wasn't particularly comfortable in the death industry. That was it. I went to the anti-war march in London in 2003 and I probably realised that I was the only defence contractor there. So, I handed my notice in within a week.”

What this interviewee revealed was that just as agents could grow to share the resident ideology of a field, some other experiences could lead

them to reject and to accept an ideology that opposed the targets of the institutions of the field. The experiences he obtained in the field of the military industry did not manage to make him share the resident ideology of this sector.

All in all, a slight majority of the interviewees mentioned at least one type of value as an incentive to join the marine energy sector. Hence, values could be considered an important determining factor of the participation in various sectors of the industry/economy. Furthermore, the conclusions of the analysis of the values of the agents of the field were congruent with the premises of radical creativity and the technological field. The agents started constructing perspectives which contained various values from a very early age, whereas the experience of participating in a sector or field led most of the time to the acquisition of the specific values that pervade this specific field. These observations were congruent with the existence of an internalisation process that co-existed with ex-nihilo creation. The fact that sometimes the participation in a specific field led the agent to reject its resident values instead of sharing them was due to the fact that radical creativity is not a pre-conscious internalisation mechanism but rather a reflexive one. Radical creativity allowed for the development of an understanding of such cases via the analysis of the values that the agent internalised in and out of a specific field and whether or not there was a conflict between those two.

Nevertheless, the most important conclusion derived from the analysis of the interviewees was that they did not envisage their participation in a particular technological sector as something 'morally neutral'. For example the interviewee that changed his career because he did not want to be in the 'death industry', cited previously, did not seem to believe that the construction of weapons was something that had nothing to do with the conduction of wars. The environmentalist interviewees declared that the development of renewable energy sectors was something that could produce a qualitatively different and more compatible with the tenets of environmentalism socio-technical reality. They seemed to suggest that the reinforcement of a specific technological field with personnel, new ideas and resources led to the generation of a socio-technical reality with specific characteristics in the future. Working in the marine energy sector and developing innovative energy devices ultimately contributes to the creation of a socio-technical reality which is more compatible with the values of environmentalists than with the values of those who ignore this specific value. Technology is not something that has to be developed in order to construct a new socio-technical reality. Technological change is by itself the creation of this new socio-technical reality.

6.2 Adaptation

6.2.1 Performed dimension

What follows after the entrance in the field is the adaptation to its 'rules', specifically, the experience of learning to perform a specific role and to produce specific types of results. I investigated the way the respondents perceived the process of adapting to the rules and interactions in the field and of learning the necessary sets of behavioural patterns. I focused on firstly the ways in which the past employment and education of the interviewees helped them adapt in their current employment and secondly on which rules of the field they found most difficult or easy to follow.

The first insight was the straightforward conclusion that studying something that was directly relevant to the object of one's work within the field was really helpful. Knowing marine engineering was necessary in order to work as a marine engineer. However, particularly intriguing were the answers of the interviewees when they referred to the impact diverse experiences had on their capability to adapt in a specific position in the sector of marine energy technology. Having a diverse set of experiences and acquiring many different types of knowledge had facilitated their adaptation in their current positions. For example the

research associate of a university's engineering department claimed that adapting to the exigencies of work in a specific position required possessing both natural science and social science backgrounds:

“I've got a scientific background, but I also had the opportunity to do an MSc which is focused on kind of business and climate change and energy issues and that sort of gave me some sort of policy and commercial awareness kind of skills... So, my scientific background is quite good because I can understand anything or most things people are saying about modelling tidal devices and the complex end of the spectrum. But I'm also able to engage with things like net present value calculations. I've got good commercial awareness of what people are talking about at the other end of the spectrum.”

Other interviewees also claimed that having already acquired many different sets of knowledge in distinct working and educational environments had rendered much easier their adaptation to the sector of marine energy. These interviewees included university research associates, members of the periphery of the field, members of public institutions and members of developer firms.

Nevertheless, this commonality of the belief that diversity in the experiences facilitates the adaptation to a new field bears a crucial implication. If some agents have a diversity of experiences in distinct working and educational environments, then that means that they have managed to adapt successfully to these environments. Hence, before having to adapt to the field of marine energy, they had already succeeded

in adapting in other environments. Therefore, if the experience of adapting in one locus facilitates future attempts to fit into other loci, then that means that adaptation is something that can be learned. As the leading member of a developer firm described it:

“I’ve had a few different roles. I worked in banking, I worked in engineering, and I worked for myself before. So I think that has helped me, given me a sort of a mentality to cope with it, because it is not easy starting up your own business and working on your own. I think if I’d work for the same company, if I had worked for IBM for fifteen years before I did it, I think I would find it very difficult not having that security there.”

This quote firstly agreed with the conclusion that adaptation is something that can be taught and secondly described the opposite effect: working in a single position for many years would have resulted in becoming less adaptable, especially if the locus in which agents would have to adapt was one of high complexity such as a start-up firm in a field of a new type of technology. However, since socio-technical reality is comprised by both the performed dimension and the independent dimension, this analysis of the adaptation of the respondents would be incomplete without an investigation of their interactions with elements of the independent dimension.

6.2.2 The Independent Dimension

This section will focus on how the interviewees adapted to the aspects of the independent dimension in their work. I will examine how respondents perceived the aspects of the independent dimension as they worked and how they reacted to some of its dictates. As soon as the agents, who were directly involved in the construction and testing of marine energy devices, entered the field, they learned that there was only a finite amount of ways to interact with elements of the independent dimension, such as, for example, the material used for the construction of the devices. This was an experience that the agents obtained and internalised as soon as they entered the field. Hence, the entrance to the field of marine energy obliged the interviewees to abandon abstract theories and hypotheses and instead to develop new, more realistic sets of behavioural patterns about how to handle aspects of the independent dimension, as can be seen in this quote from the interview of a PhD in engineering student who explained that his innovative ideas were constrained by the characteristics of the independent dimension of contemporary technology:

“So you try to be innovative and you should be innovative but stay within some logical limits of this decade's technology let's say. They don't want you to create a death star... So, I guess the limitations come from what is out

there as technology that already exists and, if it's something totally new how easy it will be to manufacture it and bring it to the public.”

The experience of working in the sector led this interviewee to realise that there were only a handful of ways to interact with aspects of the independent dimension of contemporary technology. The constraints the latter posed to future technological innovations had to be respected.

Similarly, the experience of working in the sector obliged the leading member of a construction and development firm to develop sets of behavioural patterns related to the interaction with the complex oceanic environment as can be seen in the following quote:

“I can tell you, you would never put anything in the water unless you absolutely have to. And certainly you wouldn't put rotating machinery in the water unless you had to.”

The respondent argued that water was a greater obstacle to the proper function of the device compared to other environments. The complexity of the oceanic environment was a major difference in terms of the independent dimension between the field of marine energy and the ‘sister’ field of wind energy.

Since humans are unable to induce change in the independent dimension, then some consensus should exist with regards to technical problems of the field, in which the aspects of the independent dimension

were more prominent. Adaptation to the elements of the independent dimension should be relatively similar among the agents of the field. This was apparent by the responses of the interviewees to a question about the mechanical part of the marine energy device that each of them deemed more important to its ultimate success. Marine energy devices were composed of a prime mover element, a power take off arrangement, a reaction system and a control system (Pentland Firth Renewables, 2011). I asked the interviewees which of these they considered more important for a successful innovative marine energy device.

The majority of interviewees agreed that the correct construction of the prime mover element of the marine energy device would be critical to its proper function and commercialisation, as can be seen in the following quote from a member of testing facility:

“I think the prime mover element is pretty crucial basically... I think it's going to be the prime mover element that always dictates the energy that we can take out of the resource. But after that it is all about making sure that the losses are as low as they can practically be for a reasonable amount of money. But I think getting the energy into the device in the first place is always the key.”

Only a very small number of interviewees, such as some members of statutory regulatory institutions, did not discuss the prime mover element because they worked in positions of the field that do not require knowledge of engineering. In addition, almost half of the interviewees

not only listed the prime mover element among the most important parts of the machine but also insisted that it was the only element of the device that would determine in the end which devices would be successful.

However, beyond this basic agreement about the importance of the prime-mover element, the consensus of the interviewees was not so clear. For example there were interviewees who argued that only the prime mover element was the decisive part of the marine energy device whilst others suggested that the decisive parts were the prime mover element as well as other parts of the device, such as the control system and the reaction system. Others claimed that all the parts of the machine were equally important and some of them stated that the complexity of the sea environment would ultimately lead to more than one successful design for the devices, especially in the case of wave energy. As a member of a consultancy firm put it:

“So you've got a huge range of different devices. That's why I believe that in the end there will be three or four winners. There will be more than one with wave and may be one with tidal. It's not going to be like the wind industry where everywhere they've got a stick and three blades essentially. Probably in the marine industry we'll end up with probably six, seven different devices that will work and will be used. And the key for them is that they can generate electricity cheap.”

The degree of consensus found in the data about the importance of the prime mover element confirmed that the agents of the sector all had

internalised similar sets of behavioural patterns in their perspectives with regards to the independent dimension of the field. Participating in the marine energy technology sector went hand in hand with learning the importance of the prime mover element for the correct function of marine energy devices. On the other hand, the fact that some interviewees emphasised the importance of only the prime mover element while others highlighted it as only one of the elements of the device that would be crucial to its success, means that there were differences in the ways the agents of the sector had adapted to the interaction with the independent dimension. This is congruent with the approach of radical creativity which emphasises the possibility of diversity in the views of the agents which is due to their capability to create ex-nihilo.

6.3 Summary

This chapter has confirmed that the agents of the field of marine energy were radically creative, i.e. they supplemented their capability to create ex-nihilo with the construction of a perspective. Each interviewee innovated not only through his or her capability to create ex-nihilo but also through the use of several elements of the independent and the performed dimensions of the sector which he or she had internalised over the years. This chapter discussed the patterns of convergence and

divergence in the qualitative characteristics of the perspectives of the interviewees.

The first pattern is that the career choices of the agents who worked in an innovating field were associated with specific experiences they had during their childhood or adolescence. The second pattern was that innovative fields differed from the already established fields in terms of the opportunities they offered to the agents who chose to work there. Innovative and established sectors provided different types of opportunities. Innovative sectors offered opportunities which valued more the experience the interviewees had gained in related sectors, but at the same time were much riskier than in the case of established fields. Agents who were risk-averse were less likely to join the risky innovative fields: the answers revealed that only those who were willing to work in sectors with smaller and uncertain amounts of funding joined the innovative sectors. On the contrary, those who intended to utilise the experience they had gathered in other fields joined innovative sectors more easily (e.g. those who had gathered working experience in other marine engineering sectors). The third pattern argues that a career choice had to be compatible with the overarching 'guidelines' the agents use to navigate through their lives. These 'guidelines' are their values and are of critical importance.

The remaining patterns had to do with the ways the interviewees adapted to the challenges posed by the performed and independent dimensions of the sector. The fifth pattern suggested that adaptation was something that could be learned by working in various and diverse sectors. Agents who had the experience of moving from one sector to another in the past were better able to cope with a similar change in the future. The sixth pattern revealed that there was a significant but not absolute amount of consensus regarding the agents' understanding of elements of the independent dimension.

The first step towards the answer to the anthropological question, i.e. the description of the perspectives of the interviewees was completed. The next chapter will complete the answer to the third question, i.e. the anthropological question by addressing the issue of the capability of the human agent to create ex-nihilo.

Chapter 7: Radical Creativity – Ex-Nihilo creation

While chapter six emphasised the building of a specific perspective and the qualitative content of the perspectives of the agents of the field, this chapter will complete the answer to the anthropological question by examining the other side of radical creativity. It will discuss how the agents employ their capability of ex-nihilo creation to learn, achieve a personal innovation or accomplish a societal innovation.

According to the approach of the technological field, the agent's capability to create ex-nihilo becomes more noticeable when the agent is less familiarised with an action. Accordingly, when the agent is very familiar with a specific task, then ex-nihilo creation fades into the background of an already internalised set of behavioural pattern. This is the reason why ex-nihilo creation becomes more apparent when the agents attempt to achieve a societal innovation and less apparent in the case of minute personal innovations and even more so in the case of learning.

Nevertheless, the capability to create ex-nihilo is present in all these three cases. It is for these reasons that, to address the issue of radical creativity, I questioned the interviewees about the steps they took when they wanted to complete a specific task in their work. My intention was that their answers could provide a glimpse into the way they

perceived and understood the way they worked under ordinary or extreme circumstances. It attempted to get them to describe what they considered the most significant stages towards achieving a goal, namely the sets of behavioural patterns they used in order to complete a task. The answers could include information about how their capability of ex-nihilo creation manifested itself.

The majority of the interviewees followed the same pattern in the way they completed tasks, which consisted of three steps. The first step was finding the goal, the second step was reducing the complexity of the problem at hand and the next step was working as had been decided during the two first steps. The capability of ex-nihilo creation was more obvious during the two first steps. However, there were two special cases in this pattern which will be explained.

Finally, this chapter will attempt to provide an introduction to another aspect of the function of this side of radical creativity. This aspect is the ability of the agents of the field to function and achieve the inception of innovative ideas without being noticed and with a much smaller amount of information than normally required. The agents who acknowledge the existence of this type of function of the radical creativity usually reveal that it is the result firstly of many years of experience of working in a specific niche of the field of marine energy and secondly of the idiosyncrasy of their mind. What that means is that,

the function of radical creativity becomes even more effective, the more information and knowledge of the field one has. However, working for many years in a similar position in the field does not have the same effect to all agents. Some are able to innovate faster than others with the same amount of knowledge.

This chapter will now describe the patterns that appeared when the interviewees discussed the way they accomplished specific tasks while they worked.

7.1 Completing an Innovation

7.1.1 Finding the Goal

When trying to complete a task, the first step of the majority of the interviewees was to find a goal which, if achieved would guarantee that the task was completed successfully. Without finding the goal, any further action was deemed to be out of context and unnecessary. Within this overall pattern there was certainly some diversity in the ways in which the interviewees chose their goals. Those who worked in developer firms/consortia and educational institutions chose their goals themselves whereas, to those working in private and public institutions that provided specific services to developers, finding a goal was rather more a result of

their negotiations with other institutions with which they either cooperated or had relations of clientage. An example of the first way was the following comment from the answer of a leading member of a small developer firm:

“First you have to ask yourself what’s the question, what’s the problem to solve... So you’re looking at what’s the issue, what’s the problem and you’re looking to see well what would be, what would actually be the outcome that you want.”

An example of the second category was a member of a consultancy firm, i.e. a member of the periphery of the field, as obvious in the following quote:

“Essentially, if a client comes in who has a marine renewable device, first stage is obviously for them to get them to talk with a contact, which is I. So, then, I would discuss with the client what exactly they are after, what are their requirements, what's their scope of work etc. etc.”

This divergence meant that within the field of marine energy, there was a specific core of engineers and people who worked in institutions that directly produced new artefacts and processes and had a higher degree of autonomy in terms of choosing their tasks. To state it in Marxist terms, they were less alienated from the product of their labour than mainstream workers. If there were societal influences in this process for those people,

these were not imposed directly via negotiations, but through other indirect paths. This relative isolation of technologists from direct social influences could help them specialise in overcoming the challenges the independent dimension posed to a technological innovation.

Directly influenced by other social loci or not, finding the goal was simply the first step towards the completion of a task. The next section will describe the second step, i.e. the application of methods to reduce the complexity of the task.

7.1.2 Reduction of Complexity

Addressing a problem in the field of marine energy was not easy. Usually, people who were employed in positions such as the interviewees had to deal with very complicated and risky cases. For example the leading member of a construction and repair company revealed that constructing an efficient wave device was difficult:

“There have been 20 or 30 years of research into wave devices, much more in the last five or ten years, but they still haven't overcome the fundamental issues of how you generate enough energy from waves to make it viable.”

In addition, very often huge amounts of money depended on the decisions of the agents within the field, as can be seen in the following quote from a member of a public regulatory institution:

“20 billion quid, is a rough estimate of the capital investment planned for wind-farms in Scotland... You have this combination now of huge, huge financial investment being currently resting in the licensing process which rests upon the government policy, the government economic policy, the government's economic position, the government's economic aims for the country. It's a really interesting mix.”

The substantial technical challenges and big financial risks observed within the field of marine energy technology meant that failing to achieve a goal in the field was both easy and expensive. To avoid mistakes and failure, after finding their goal, the agents of the field tried to find ways to simplify their projects. There were various methods for doing so.

The most common method was the collection of all the necessary information. A typical example of the function of information gathering within the field is the following extract from the interview of a leading member of a consortium of investors and developers:

“I mean generically you'd scope the task, you'd prioritise it, gather knowledge for the nature of the task, put together a project plan, allocate resources for that plan, look at the funding issues as well as the matter of your resources, and, if it is further necessary, gather any approval you will need to actually carry out the task.”

The interviewee mentioned that gathering many different types of information was a necessary element of the successful completion of a task. The complexity of the function of institutions in the field meant that a prerequisite for the achievement of a goal was the concentration of many different types of information, such as information about sources of funding or about the 'nature of the task'.

The complexity of information gathering is one of the reasons why consultation was of particular importance for those institutions that provided services to the developers. It made faster the collection of information. Many of the interviewees described some type of consultation as significant, either discussion with clients or brainstorming with other people working in an institution or other cooperating institutions. Consultation is necessary due to the tendency of modern societies to generate specialised rational bureaucracies. Specialisation in late modern technological fields has advanced so much that there are (inter)governmental programmes which specialise in conducting research to provide consultation. Examples include the 'EU Beyond Progress' listed by the leading member of the consortium of investors and developers and 'Space', the independent research centre in the Scottish Parliament, listed by the Green politician.

Furthermore, the importance of consultation could not be more apparent than by the existence of specialised institutions created exactly in order to collect and provide information. These are the consultancy institutions of the periphery of the field which usually gather information through conducting their own research. Their contribution is explained by one of their members:

“I suppose the most important contribution has to do with... Obviously we do a lot of research... There are a number of people looking at these issues... Once published, they can bring down the costs for marine renewables. And overall that's important because if it's going to take off the overall cost for developing and installing these devices has got to be significantly reduced.”

The respondent mentioned that his institution specialised in conducting research which, once published, could be used to reduce the cost of development and installation of marine energy devices. Without the contribution of consultancy firms, developers would have to conduct this research themselves and this would significantly delay the completion of an innovation.

Moreover, consultation was crucial to the achievement of the goals of people in institutions whose work involved a lot of negotiations with clients. To give an example of the latter, an engineer of a distribution company, responded:

“First of all I have to work with the marketing team. And there is a marketing team specifically that deals with energy efficiency and sustainability, not just for my purposes. So, when I have in my mind new products or a new process, I have to talk with the marketing if this solution is going to be viable in terms of the marketing, if there is another company that deals with that product, is this product different than other companies, in how other way we can use this product, are we going to have any sales in the future, is this product energy efficient? So we have to check all the environmental legislation in the UK in order to say yes, this product or process is energy efficient and we're trying to make something like a marketing report that is going to include the marketing in the UK about this product and all the legislations. So, when we finish with the marketing, then I have to talk specifically with the sales engineers in my company, I have to talk and see if they are willing to proceed with that product and sale that product to the customers. So, if the marketing says yes and the sales' engineers say yes, then we will try to make a team, specifically for this product.”

Here, consultation was not only mentioned but it was rather described as a very important component of the process of completing a task in her work. It was also a standardised procedure. The member of the distribution firm described two stages of consultation each with a specialised institutionalised team, i.e. the marketing team and the sales engineers' team, without the approval of which the propositions of the interviewee would be abandoned. The standardisation reveals that there is a higher degree of complexity when it is necessary to maintain relationships with other agents and institutions. It is a necessity to reduce

the amount of autonomy while completing the tasks and to assign some of the work to others like specialised bureaucratic agencies.

When consultation did not suffice for the completion of a task, the agents of the field applied another method to reduce complexity. This method was the creation of a plan that specified the steps by which the goal would be achieved. It was very prominent in the answers of the core of PhD students and developers, i.e. all those that directly produced the technology whilst it did not appear as much in the data derived by those who worked in the institutions that provided other services in the field. In general, researchers and developers stressed this stage of the process of innovating much more than consultation because it was a much more critical stage for their work.

There were many different ways to form this plan. For example, a research associate of an engineering department claimed that he and his colleagues formed plans after thorough discussion, brainstorming and exchange of ideas:

“When we have a specific task to do, normally the first thing we do is sit down and discuss it. ... So we sort of sit down, discuss our ideas and form a plan and hope that everything goes according to that plan. And then we have further meetings on that task. I'll curve up some issues and also discuss those, bounce those around, see what my colleague thinks of those.”

To others, such as the following PhD student, the formation of a plan was possible only after they had divided the task into smaller, simpler tasks:

“So I try to design an experiment that will achieve the specific purpose. Then, the next thing is thinking about the steps that are going to be involved practically and writing or planning in my head a list of action items. Then, following that would be making sure that everything that's needed is available. And after that would, you know, set it up and do the experiment. And afterwards you would analyse the results and try to make sure that they make sense and that you got what you wanted.”

A third way to develop a plan is backwards analysis of the task at hand as can be seen in the following quote from another PhD student:

“So, what I usually do is work backwards. OK, I want to achieve something like this and this, I move backwards to see how I am going to reach that, what I need to do to reach that result.”

Brainstorming, backwards analysis and the division of a task into smaller and simpler tasks were all sets of behavioural patterns which helped reduce the complexity of the problem at hand.

So far, consultation, gathering of information and planning belong to those methods to reduce complexity that can be more or less described as institutional practices. They are instituted sets of behavioural patterns that have specific things in common but are not identical enough, i.e. to

the point that they could be standardised, recognised and named as such. There were, however, other practices performed in such a standard way that had a specific name. For example, when the leading member of a statutory institution conducted scientific research, he used a risk analysis approach to prepare a plan that would reduce the complexity of the task at hand:

“Effectively what we do is we take a risk analysis approach. The problem that's presented to us normally comes as a fairly set of end-point type problem or just expressed as ‘We don't, we can't do something on’, I don't know, the interaction of birds with particular kinds of in forms. And what do you do? You break down the problem and you try through a risk analysis approach what factors are involved, what we know about the functional relationships between the issues. whether the functional relationships between the steps and the risk analysis is, is where the problem is.”

The interviewee claimed that the standardised risk analysis approach, which involves the division of the task into smaller simpler tasks, guaranteed the reduction of complexity and the easier accomplishment of tasks.

This tendency becomes even more apparent in engineering. As can be seen in the following extract from the interview of a PhD student from a university engineering department, after the application of a standardised process of experimentation in order to reduce complexity, engineers were further able to use specific innovative artefacts such as

simulation software. These technological entities allowed for the standardised emulation of experiments in the surprise-free environment of the computer:

“Once I have an idea, I start experimenting and I use simulators, simulation tools. Basically most of my work is on computer programming and simulation tools. So, depending on the task, I try to think of what are the necessary let's say equations or manufacturing details that I need as inputs, what the inputs should be, what the outputs should be and then I work in the in between, I mean on the programming. There are many versions, version one version two, and version three, depending on how fast the programme is and how good the results are.”

Hence, the use of simulation software allows for the first stages of experiments to be conducted in a controlled and much less complex environment. Without them, the agents of the field would have to resort to other, less efficient, methods for the reduction of complexity and their work would have been much more difficult and expensive (Jones, 2012).

My final observation about these two first steps towards the completion of a task has to do with, the process of learning. Those interviewees, who decided to describe tasks which included learning, revealed that the two first steps towards learning something also followed the same pattern. First they found the goal (in this case the thing they had to learn) and then they reduced the complexity of the learning process.

For example, the following student described the process of learning how to use a simulation software package:

“Well, I first find the software package. Then I look like for a person that knows it in the college. Then I'm looking for manuals or a website where they give, where it gives online support. And once, ideally if I have like a manual, then I follow the manual to learn the software. And of course, if the manual is good and has some examples, then it makes it better, it makes it easier learning the software. Yeah and then, when I'm done with the manual then ideally as well, I apply what I've learned, so that I have an example of that I know what should be the answers that I would be expecting... So that I am sure that I know and that I am using the software correctly.”

Not surprisingly, and exactly as the concept of radical creativity suggested, the process of learning followed the same pattern as the process of innovating described by other interviewees. Firstly, he found the target, i.e. he found the software programme he needed. Secondly, he gathered information and reduced the complexity of the task by reading a manual. Using examples to check the results could be something analogous to experimentation albeit with the opportunity to check easily if there is a mistake. This agrees with the hypothesis of the approach of the technological field that innovation is a phenomenon that is not limited to the case of the construction of new technological artefacts or the generation of new scientific knowledge. Instead, all types of learning can be understood as personal innovations.

7.1.3 *'Feelings' and Innovative Thinkers*

Even though the methods used to reduce the complexity of tasks were applied and appreciated by the majority of the interviewees, there were some respondents who claimed that they did not need them as much as others. The reason was that after a certain point they relied more on their intuition and not on the use of methods to further reduce the complexity, when they wanted to solve a problem. A leading member of a testing facility described this alternative way to complete his tasks, as can be seen in the following quote:

“I'm very good at describing the entrepreneurial trade. I'm very good at getting the right answer without all the information. I'd say that with about 50% of the necessary information, I'll get the right answer about 80% of the time. With 80% of the information I'll get the right answer 100% of the time. So, I'm quite intuitive and I can bridge the gaps of missing data, information, whichever, I can usually come to the right conclusion.”

He did not rely on standardised procedures but rather on his intuition to facilitate his work. In fact, he was so reflexively aware of and accustomed to this intuitive effect that he could offer a mathematical function of the correlation between the percentage of information available to him and of the correct decisions he could take thanks to his

intuition. Similarly the leading member of a small construction and development firm knew when a solution was reached by a feeling he had:

“You know when you've got a good solution. You know when it's right, you know, there's times when you're struggling about this thing that doesn't quite work and then the last few bits click into place and now this is the solution, this will work. And then you can present that to the client and hopefully you'll get a contract and get the opportunity to do it.”

It is impressive that these agents claimed that they had the capability to reduce intuitively the complexity of their tasks even in the extremely specialised and scientific late modern technological fields.

When asked about the origins of this capability, both of them argued that the accumulation of experience in the sector helped them developed it. As can be seen in the following quote, when asked about the origins of this ability, the member of the construction and development firm suggested that it was the combined result of the accumulation of experience and the good communication with his colleagues:

“Yeah it just takes time and then also brainstorming is good, getting other people to tell their opinions because you never know where part of the solution pops up. And then eventually, it just all seems to fit into place and then you know... Yeah, it's a bit of experience I would say.”

Experience was also the main factor mentioned by the leading member of the testing facility. However, he was much more uncertain and did not negate the possibility that other factors such as inheritance might have been important:

“It's probably a mix of things. I don't know that I was ever taught it. I don't know whether it was inheritance or whether it is something that evolved in my time. I'm old enough, and hopefully I have done enough that this is lessons learned that enables me to anticipate results based on previous experience... This is where my experiences, let's say for example in offshore wind, which is a very high level, a very, very large sums involved, millions of Euros, reflects in and works well with the wave and tide industry which is about 50 years behind. ”

Their argument was that, in some cases, large amounts of experiences could help an agent in the field to develop insight, i.e. to become able to solve problems without analysing them.

A possible interpretation of these answers is that they did not reveal a genuine capability of those interviewees but rather they are an effort to enhance their self-esteem (Fielding and Thomas, 2008). Furthermore, it could be a reflection of their positions in the field as leading members of institutions therein. Bourdieu claimed that highly skilled agents of a field tended to misrecognise the objective power relations in which their work efforts unfolded (Burawoy, 2012).

Nevertheless, I should be very cautious before proclaiming that their claims to insight and intuition are simply a type of enhancing their self-esteem. It is at least probable that the interviewees are narrating instances when automatic innovating processes did occur. If that is the case and if they gained this capability through their experiences in the field, then the agents who were more experienced required less reduction of complexity before creating ex-nihilo. However, it is very difficult to understand such a capability. Bourdieu's 'logic of practice' (1980) is unable to provide insight for such a phenomenon. The respondents did not describe conducting a habitual non-reflexive action which had been internalised in the past through their habitus. They described an innovative action based on the recreation of only a few aspects of pre-existing socio-technical reality. If it was so, then it was the clearest appearance in the data of the capability of radically creative agents to create ex-nihilo. Ex-nihilo creation in this case was possible only after the agent had already internalised a large number of sets of behavioural patterns related to his or her work.

In any case, only further research of the radical creativity of agents with a significant amount of experience will reveal if this intuitive capability is or is not a factor that has to be considered when analysing technological innovation.

7.1.4 After These First Two Steps:

After finding the goal and reducing the complexity of the task, the interviewees usually said that they proceeded to the choice of a solution, and then to the implementation of that solution. Even though these two steps are as important for the completion of any task as the two already discussed, the vast majority of the interviewees did not describe how they executed them. They chose to emphasise the two first steps of the process, because it was during these steps that the course of action they would take had been decided. During the two last steps of the process, the respondents simply implemented the decisions they had taken during the steps of finding the goal and reducing the complexity. Therefore they did not describe them, because the critical stages for the completion of a task, i.e. the completion of a personal or societal innovation, were the steps of finding the goal and reducing the complexity.

To sum up, the majority of the interviewees followed a pattern which consisted of finding the goal, reducing the complexity, choosing a solution and implementing it. The next section will explain that this pattern reveals a lot about firstly the way the respondents used their capability to create ex-nihilo and secondly the relations between this capability and the perspective of their radical creativity.

7.2 Radical creativity

Before proceeding with the analysis of ex-nihilo creation, it is important to remember, as I argued in chapter three, that the concepts of the habitus and the radical imagination contain ideas which are also present in the concept of radical creativity. After all, the concept of radical creativity aims to maintain their strengths and abolish their weaknesses. These ‘ideas’ are the existence of a type of habitual behaviour that can be recognised as ‘stable’ both by the person that behaves that way and by the people with whom she or he interacts; and also the existence of reflexive behaviour which does not constrain itself in specific cases but at the same time depends on learning. These two types of behaviour are possibilities and not necessities. Human behaviour can be either habitual or reflexive or a combination of the two. The only necessities are that both these two types of behaviour are necessary to accomplish specific tasks, and that they are both present in any type of human action. Finding how they work however depends on the type of action and is an empirical problem. Therefore, the previous analysis of the data and the patterns can be used to uncover how the radical creativity of agents functions.

The first observation based on the data that is relevant to this analysis had to do with the elements that the interviewees included in

their answers when they responded to the way they accomplished tasks. As discussed previously in sections 7.1.1, 7.1.2 and 7.1.4, most answers followed the following pattern:

1. Finding the goal
2. Reducing the complexity of the task (via a combination of collection of information, consultation and/or planning)
3. Choosing a solution/a schedule of work
4. Doing the work

The first thing that should be noticed regarding this pattern is that the interviewees were able to recollect and re-narrate not only the way they worked but also the most important steps towards the completion of the duties of their work. Re-narrating the process of their work means that they were capable of recreating it more or less in their minds and this was possible because they already possessed a high level of knowledge about the methods they employed in their work. The second, and perhaps most important, were the range of points they included in their answers. Section 7.1.4 revealed that almost all the interviewees chose to list, in the actions they took, the steps towards deciding how to complete a task and not the steps towards its completion after the decision was taken.

This of course does not imply that they could not recollect how they implemented their decisions. It simply means that the majority of the interviewees believed that these steps were the most important towards

the completion of a task. They were the sine qua non for successful work. They were the moments when radical creativity came into action and generated new realities. Hence, it is really interesting that these steps, as could be seen in sections 7.1.1 and 7.1.2, were also those which included a lot of reflexive thinking, as evident in things like thinking about what the goal is, evaluating information, brainstorming and in general exchange of ideas and information and, last but not least, choosing a solution. The reason for this ‘coincidence’ might be the fact that any innovative action includes a procedure of reflexive thinking during which the radical creativity of agents generates and evaluates new ideas. The interviewees chose to follow such a pattern because it was during this procedure that the most important elements of any subsequent action were decided. This subsequent action then is ‘business as usual’ or, more accurately, ‘business as decided’. Business as decided was a process during which the respondents did not have to re-consider what they had already decided. Their reflexive thinking was reduced to the implementation of an already taken decision. Only in the case of unexpected problems did they start to consider the same issues and repeated the pattern described previously, as can be seen in the following quote from a member of a public regulatory institution:

“You look at the problem. You assess what it means and identify a set of solutions. Once, from that set, once I've

identified this sort of set of solutions, I discuss it with senior management within the organization and see if they've got a preferred solution or if indeed they have an alternative solution that I haven't identified.”

Hence, after the initial emotional response, the respondent argued that, in case of an unexpected problem he repeated the process described previously. The first step was to understand the challenge and find a ‘set of solutions’, i.e. to find the goal. Then he made sure he reduced the complexity by discussing it with senior management in his institution and then he reached a solution.

Furthermore, the data in sections 7.1.1 to 7.1.4 revealed that it was exactly during the moments when the interviewees were thinking reflexively that they were also accumulating the most information. The whole process of reduction of complexity consisted of various methods of learning and accumulating information, whether this was information from existing literature, advice from seniors or analysis and breaking up of a task. But all this learning did nothing but distributed the knowledge that already existed within socio-technical reality. Parts of this knowledge had to do with the social locus in which the agents were found and in this case, the field of marine energy technology. Through their experiences the agents of the field learned what the field considered capable of changing and what was considered stable. Of course, due to the complexity of the human psyche, as Castoriadis (1975) would put it,

these categories were never identical in each human. Each human agent, no matter how identical his or her learning experiences are to the experiences of others, can and will possess a number of differences in what she or he treats as susceptible to change. This was obvious in the discussion about why the interviewees chose their careers. Each of them listed a different mix of early age experiences, values and personal incentives as the reason why they participated in the field.

Hence, the internalisation of external structures by accumulating knowledge and imagining/representing it in the human psyche, as Castoriadis (1975) would put it, is a prerequisite for successful (in terms of achieving a goal) reflexive thinking and not something that can substitute it. This conclusion can be further justified by the persistence of the presence of this pattern's elements (such as finding the goal and reducing the complexity) even in cases of learning, as shown in section 7.1.2. This suggests that personal innovations are present continuously in the life of an agent, since they all have to learn how to react in many different work situations. Hence, the completion of tasks, of even the most insignificant tasks requires the perplexed combination of two elements: of creative reflexive thinking and of the accumulated knowledge of the conditions of the technological field.

Finally, combining the analysis of this chapter and the analysis of chapter six, leads to another conclusion. This conclusion is that the more

the agents participated in a technological field the more apparent the origins of their creative thinking on the knowledge of the conditions of the technological field became. The analysis in this chapter revealed that accomplishing a task led to a personal innovation and the internalisation of a new set of behavioural patterns. This internalisation guaranteed the successful completion of this task in the future. The analysis in chapter six suggested that the more the interviewees participated in a sector, the more knowledge they generated regarding its characteristics and the more adapted they became in working there. The knowledge they obtained was not strictly technical knowledge that had to do purely with elements of the independent dimension. It was also the internalisation of many enabling and constraining factors that existed within the technological field. As the amount of time spent by the agent within the technological field rose, the increased accumulation of this type of knowledge would in the end lead to the interesting result of developing a 'logic of practice' (Bourdieu, 1980) about the field. This happens when the agents who work in a sector are able to recreate in their perspective of their radical creativity the majority of the sets of behavioural patterns which are necessary to survive in a field. After that, agents have the capacity to work successfully in the field for as long as the conditions in the field do not change very abruptly.

The analysis of the interviews does not contradict the conclusions of the theoretical approach of the technological field. I can say that creative thinking which is based on the roots of accumulated knowledge is just a long way to describe *radical creativity*. This concept can be otherwise defined as the creative activity of the imagination which takes place within a perspective, i.e. which has its roots in another creation: the knowledge which the agent has accumulated over the years in the field. This knowledge is not a representation but a creation as well. The agents do not internalise passively the information with all the socio-technical phenomena they encounter. Instead they reflexively choose to recreate and use the knowledge they have reflexively in the past chosen to acquire.

7.3 Summary

This chapter aimed to trace the capability to create ex-nihilo of the agents of the field. The interviewees revealed that innovation occurs during a process which consists of the steps of finding the goal (i.e. the problem that has to be solved), reducing the complexity of the problem, choosing a potential solution and implementing this solution. The second step of this process, i.e. the reduction of complexity, can be achieved firstly through the use of many methods such as brainstorming, division

of the problem into smaller tasks and backwards analysis and secondly through the utilisation of technological artefacts, such as simulation software, specifically built for this purpose. Moreover, it is possible that there is another way to think creatively. This way is through automatic evaluative processes, i.e. insight.

The interviewees' responses confirmed that personal innovations such as learning and societal innovations occur through the process described in the paragraph above. If that is the case than the internalisation of experiences of the performed and independent dimensions and reflexive thinking should not be regarded as substitutes but as complements. Just as the concept of radical creativity argued, reflexive thinking takes place at the same time as the recreation of the conditions of the external world. Without the recreation of these conditions, reflexive evaluation and problem-solving would be impossible.

With these concluding remarks, the answer to the anthropological question, i.e. the question about the relation between human behaviour and technological innovation, is hopefully complete. I have described how the agents innovate. To find out the objects of their innovative actions, i.e. to describe what they decide to change and what they consider stable, I will have to describe the social loci in which they are active. Hence, it is time to address the institutional question, i.e. the

question about the interactions between institutions and the dynamics of technological innovation, and to apply the conclusions of the analysis so far to the investigation of the field of marine energy technology.

Chapter 8: The Frontiers of the Field

The description of the radical creativity of the interviewees that I conducted so far is useful only as long as it leads to an – as accurate as possible - description of the institutions of the sector of Scottish marine energy technology and of their interactions, i.e. as long as it answers question four, the institutional question. To answer this question, this chapter will analyse the relation of the field with other social loci whereas the next chapter will describe its internal characteristics. I will try to demonstrate as clearly as possible the impact of these two features upon the technological innovations produced by the field of marine energy technology.

Before proceeding with the description of the field, I have to point out that the internal characteristics and frontiers which can be observed in a technological field are not the institutions themselves and their initiatives per se. Had they been, then the approach of the technological field would bear no difference from empiricist accounts which simply identify and note down diverse types of data without any evaluation and analysis of what these data really mean for the understanding they seek to develop. It is exactly the latter that the approach of the technological field can provide: it can move beyond the surface of the description of the specific institutions, agents and actions.

It can understand what these case-specific empirical data signify in terms of power relations and pertinent values within the performed dimension, about the technological field and its relations with other social loci. Hence, using this approach, I was able to understand what these responses brought to the table regarding the orientation and speed of technological development and then see what I could extract to apply to research in other technological fields. All in all, the internal characteristics and frontiers of the field described in this thesis were *innovations*, i.e. novel interpretations of the data that allowed for the identification of the characteristics of the performed dimension.

The description of the frontiers of the field precedes that of its internal characteristics. It was necessary to understand how the technological field related to other loci of the performed dimension and then to analyse its internal characteristics. The reason was that neither the technological field nor the radical creativities of its agents were created in a void. They were founded upon previously existing formations of the performed dimension. To put it bluntly, the inability to understand the relations of the field with the rest of the society would also render me incapable of understanding the origins of the values dominating the field. Knowing why the technological field was different from or similar to other loci of socio-technical reality was the best available way to understand its relations with these loci and the way they

interacted. It was only then that it was possible to observe the intrinsic characteristics of the field which existed only there.

Furthermore, beyond the identification of the frontiers of the technological field, I also investigated and examined the qualitative characteristics of these frontiers. The reason was that there were many different kinds of frontiers. There were frontiers with a strictly separating effect and there were frontiers that both separated and linked two different social loci. Understanding the technological field required the identification of its frontiers with other socio-technical loci and the examination of the ways in which these loci influenced each other. This chapter will present in detail the interactions between the technological field of Scottish marine energy on the one hand and the socio-technical loci of the market and the financial field, other technological fields, such as the oil and gas sector and, finally, some parts of the public of Scotland on the other.

8.1 Is There a Field? Searching for Borderlines

The field of Scottish marine energy technology is obviously a part of Scottish society, i.e., part of the performed dimension as it developed in the geopolitical area known as Scotland. It is quite natural that there would be some very strong links between the field of marine

energy and other sectors of the Scottish society. However, it is important to point out that the existence of these links did not mean that the technological field could be identified as a random 'portion' of this society. Instead, it was characterised by a degree of autonomy, i.e. by the presence of a set of imaginary values, as Castoriadis (1975) would put it, which were included in the formation of the radical creativities of agents within the institutions of the field and not of those out of these institutions. I discovered that these distinct values could be observed not only in the conclusions derived from the analysis of the answers of the interviewees but, on the contrary, that the latter were able to reflexively understand, locate and analyse them.

However, even before the analysis of the interviews, the partial autonomy of the field of marine energy could be easily demonstrated by the creation of institutions specialised in dealing with this type of energy. These institutions could be either mostly autonomous and performing functions which did not previously exist, such as for example the testing facilities of the sector, or sections of previously existing institutions designed to deal specifically with marine energy, such as specific institutes of university departments. The emergence of a large number of institutions purposely designed to handle a specific type of technological artefact was an easy way to find the traces of the existence of a new technological (sub) field in the performed dimension of Scotland.

The next step was to find out in which terms the field of marine energy technology was autonomous and in which heteronomous. The clarification of points of autonomy and heteronomy within the field was the most efficient way to understand what the frontiers were. It was necessary to find via which control mechanisms and instruments the field is forced to comply with the values of the performed dimension of the Scottish society. It is even more necessary to point out that this is one of the advantages of an analysis of empirical data led by the theorisation of the technological field: the ability to analyse any type of influence or interaction as it is actually exhibited within the field without maintaining any prejudices about how firms, the state and any other types of institutions behave.

8.2 A Fence or a Well-Paved Avenue? – An Ambiguous Determination

The first and perhaps the most important control mechanism was the provision or lack thereof of funding. This was not surprising due to the high cost of developing new technologies, especially in the domain of energy that was privatised in the UK. I was not astonished therefore when I found out that, even though a large amount of public money was spent on marine energy by the Scottish government (Jeffrey et al., 2012),

only research that was able to acquire some investment from the private sector of the UK or from overseas in the field had managed to escape the fate of remaining a plan in the mind of an enthusiastic engineer or director. It would not be far-fetched to claim that there was a clear ultimate determination of research in marine energy technology by funding derived from the private sector and the overseas markets, since there was no public energy company in the UK, as the following extract from the interview of a member of the Green party revealed:

“I'd love it if we had a big publicly owned energy company in Scotland. You know, at the moment we're welcoming in some publicly owned energy companies from other countries, you know, other northern European governments. That's fine, but it would be nice if we had our own. We don't and so it's a largely private sector led enterprise.”

All in all, the absence of alternative development paths, beyond the one in which the private sector is the protagonist, obliged the developers, engineers and enthusiasts in general of marine energy to depend on the funding provided by the private sector. Hence I was not surprised to find out that this ultimate determination by the private sector was evident in the answers of all the interviewees. Nevertheless the views of the interviewees regarding the benefits of this determination depended on their respective positions within the map of the field.

Respondents who were active in the more ‘fragile’ locations of the field, like PhD researchers who had just entered the field, members of small developer firms who developed alternative types of devices and business models and members of testing facilities which supported the early stages of a device, tended to maintain a more sceptical attitude towards private sector funding and to point out the weaknesses of this method to acquire investments. For example a leading member of a small developer firm, argued that one of the greatest problems in the sector of marine energy was what he called ‘quick book mentality’, i.e. the expectation of investors to retrieve their vested capital in just three years after the investment. He considered that this was a very small amount of time for the development of an industry such as marine energy technology:

“I think unfortunately here in the, in the UK, in Scotland, there is that, there is very much a quick book, a quick return is expected on investment... If you want to build up big industries, engineering, innovative industries, that requires a longer time horizon in terms of investment. Countries like Germany and Japan understand that, have it and their financing is gift to that. We don’t have that in the UK unfortunately. I think that’s one of the biggest problems that we have, is that, you know, investors just want to come in and see everything turned around in three years.”

This view regarding the quick-book mentality demonstrated that there was not necessarily a direct relationship between corporate monopoly

profits and successful technological innovations. The reason, according to the interviewee was that investors in the UK hesitated to support long-term projects, such as the development of specific types of technology.

Of course this conclusion could be rightfully derived only under the assumption that the market for investments in marine energy belonged to the categories of monopolistic competition or oligopoly (Nicholson and Snyder, 2008) and therefore there were some monopoly surplus profits in the first place. However, it would be really difficult to hypothesise a perfectly competitive market structure in this sector because, firstly, due to the absence of closure in the sector, there were no two models of devices which were identical (all were slightly diversified) and secondly the large building and installation costs meant that the entrance in the market was not easy. If the first of those two factors was the most prominent then it could be described as monopolistic competition. If the second bore more importance, it was an oligopoly (Nicholson and Snyder, 2008).

Furthermore, the sceptical attitude of the interviewees who were active in the more fragile positions of the field was not due only to the 'quick book mentality of investors'. One interviewee was hostile to the financial sector because the latter was not simply a source of investment but an investment in itself. He did not regard the financial sector as a simple source of funding but as a competitor. Financial products such as

derivatives provide opportunities for quick and lucrative returns and are highly compatible with investors who have a quick book mentality. The competition between technological fields and the financial sector is obvious in the following quote from a leading member of a small construction and developer firm:

“Well, I get the feeling it [i.e. engineering] doesn't have good street cred. I think that in some ways I am quite pleased with the current economic crisis going on since three or four years ago, because everybody wanted to get into finance and banks and selling stuff anyway. But actually science and technology is I think very important because it has a very important contribution to society. And building stable power generation so that we can live our lives passing them in harmony without harming our planet our environment, I think this is important, you know.”

The respondent regarded the financial sector as an important source of competition for funding and personnel. The interviewee emphasised the contribution to society of his own field but neglected to mention the benefits of the existence of the financial sector. This is congruent with the theory of the technological field which suggests that agents positioned within a specific technological field tend to value more their own experiences and needs when they shape their opinions.

Whilst the quick-book mentality and competition with the financial sector could be more of an obstacle to small firm-led types of technological innovation, at the same time it was what members of big

investment consortia thought would guarantee the success of their ventures. To be more specific this analysis was important because it helped identify how the differences in the views of the interviewees depended on their location in a field. This could not have been more eloquently demonstrated, than with the contrast between the previous quote and the following extract from the interview of a member of such a consortium:

“I think that actually Scotland is particularly well placed, because there's a lot of local government encouragement for the Scottish based industries and other industries coming to the location. And they get a lot of broad support to establish themselves. And certainly the marine environment around Scotland in terms of potential tidal and wave energy is very lucrative. So, you see the number of companies that are...actively being encouraged to establish and develop themselves in Scotland and branch out from there. I think that the long-term problem is that where there are renewable offshore certificates to encourage this investment, this often does not sort of support innovation. People, they dive in and start to generate electricity without looking at the long-term cost, because it's offset by government subsidies. So, I think there is indeed a need for funding in the [name of consortium] to sort of encourage utility companies to sort of look at innovation look at commercial potential, so that they will not rely on long-term government plans and subsidies.”

This interviewee, when responding to the exact same question as the leading member of the small developer firm, avoided criticising the ‘quick-book’ mentality, and claimed that the development of the sector

could be achieved more efficiently through the investments made by large corporations such as those which comprised his consortium. He suggested that the type of investment that should be marginalised even more was public investment in the form of government subsidies because it encouraged firms to ignore the long-term cost and generate electricity in a non-survivable way in the long-term, after the government subsidies would necessarily stop. He did not seem to worry about the fact that these government subsidies might have been one way to maintain the necessary influx of investment required by technology which had not been able to develop using 'quick book' investments. Instead, what he proposed was the clearance of the field in favour of investments made by large consortia, specifically by the institution in which he worked.

The arguments of the member of this consortium could be interpreted as a specification of the arguments of neoclassical economic theory for the sector of marine energy. Only the perfect competition, i.e. a market with minimum public intervention where the rules of laissez-faire dominate will reproduce the inevitable long-term conditions of the market (Nicholson and Snyder, 2008; Mankiw, 2010). Any public intervention is a distortion that gives false hopes to many developers who will believe they are productive and able to compete only due to the subsidies. In the long-run, when the distortion will disappear and the long-term cost will reveal itself in all its glory, these developers will be

forced to leave the market. Hence, the only way to avoid wasting money and developing a moribund industry would be to leave the progress of marine energy to the hands of those that are already able to compete.

And of course, in a 'privatised' world, the only way to acquire or develop these technologies was via the provision of funding by the private sector. Similarly, when asked about the most important problems of the field of marine energy, beyond topics which had to do with funding and more precisely the 'quick-book mentality', a very common answer had to do with the reduction of the cost of production and installation. This reduction would be possible only after receiving funding from the private sector and conducting research. Moreover, I noticed that most interviewees believed that wave energy devices were not yet successful not because they could not retrieve energy by the motion of the waves, but because they could not do so in a way that would be economically as or more efficient with other sectors of the Scottish economy such as the oil and gas industry and the financial sector. An example of this view was the following extract from the interview of a leading member of a construction and repair company:

“In wave and tidal devices, getting funding for developers is extremely difficult. So, that's the first problem... Then it is very much down to how easy it is to deploy these devices and, although I think it's becoming easier, I've seen problems on the way to deploy devices and to establish testing areas because they are competing with

other demands on the areas that are needed. And then beyond that, we've got a fundamental problem that, even though tidal devices are starting to show commercial ability there are no commercial wave devices developed as yet. So, the actual pure technology isn't there and has to be developed. So, the fundamental problem is, is there ever going to be a commercial wave device and how is that going to be achieved?"

This extract supported the argument that technological development is ultimately determined by economic factors and, in this case, the private sector. In modern capitalism, commercial success and economic efficiency are essential parts of any successful technological innovation.

This is a key characteristic of any technological artefact and defines the frontier between the technological and the scientific field. The scientific field differs from the technological because it excludes social and personal interests from the hard core of science, at least in the case of the fields of hard science (Lakatos, 1970). It is irrelevant if the knowledge claims it produces will be applied somewhere. Developing knowledge that always refers to an economically efficient materiality is an idiosyncratic characteristic of technology which separates its field from the field of science.

The determination of the technological field by the private sector however, does not limit itself in the adherence to key criteria of any capitalist economy such as market efficiency. The private sector transmits even secondary characteristics such as for example the criteria

of marketing. The latter are not perceived by the interviewees, and especially by those in the early stages of development of a device, as secondary components of the process. In fact they argue that successful marketing can be the thing that separates successful devices from shelved ideas. The following quote from a PhD student is quite revealing:

“I’m not sure how do they evaluate different research projects but it more or less depends on how you tell your research projects, so it’s becoming more marketing basically, because finding a catch name of your research project instead of a very technical name, even those things may help. So, from research you have to concentrate on how I will find funding for this project. I think this is the main problem for supervisors especially, because in our case my supervisor doesn’t have time for actual research because he has set up lots of meetings, lots of funding things, applications, that sort of things.”

This PhD student not only pointed out the importance of marketing but went even further. He implied that marketing was as of equal importance to the eventual construction of a device as its technical characteristics and economic efficiency. Additionally, this quote hints at the internal conflicts of late modern market economy and how they were expressed and eventually influenced the field. In the case of the marine energy perhaps what could be observed was the struggle between the competing models of hard capitalism based on industry and soft capitalism based on the construction of needs via marketing (Thrift, 1997).

Finally, I found that the interviewees who tended the most to cite problems unrelated to funding when asked about the obstacles in the development of marine energy technology, were the employees of the public sector and particularly those whose responsibility had to do with the control of the environmental consequences of the offshore installation of devices. One of the best examples was the following extract of an interview of a leading member of a statutory institution which regulated renewable energy sectors:

“The industry has got lots of challenges. The wave and the tide people have got technological challenges to get devices that would be able to withstand the environment they are going to be placed. And then certainly there are the challenges regarding the impact these devices will have on the environment, particularly in relation to birds, mammals, fish etc... There are some significant technical challenges with regards to developing the industries in the sense that you're moving the industries on from lots of shallow deployments to what's deeper deployments which means that they then have to meet the challenges of having to put larger turbines in the sea.”

Again, this is a straightforward conclusion (after all, regulating the markets to protect the environment is their exact job), but is related to the fact that free market economy has not yet managed to develop private sector-led institutions and control mechanisms capable to prevent environmental degradation.

To sum up the argument of this section, the dependence of the field on funding received from the private sector is perhaps the most important 'source' of heteronomy in the field of marine energy. The absence of a public company which would be able to undertake the majority of the funding in the sector meant that the development and exploitation of marine energy in Scotland and the UK in general would have to respect the needs of the private firms that were willing to invest in the sector. And the very high construction and installation costs meant that within the contemporary globalised oligopolistic economy, the realisation of many of the most promising development paths of the wave and tidal energy devices depended on the desires of a handful of corporations such as those that participated in large investor's consortia.

However, this was not the whole story. The views of the interviewees who worked in more fragile niches of the field (e.g. PhD students) were a clear example of a reality in which the relations between the financial and the technological fields were not always harmonious. Innovation in an engineering field such as the field of marine energy technology was neither a process whereby the engineers and developers happily produced the machines and instruments that the investors desired in the form that they required nor a procedure where the investors joyfully funded any project proposed by the technologists of the field. Nevertheless, the observation that those who complained were the

'fragile' agents of the field led to the conclusion that it was the financial sector that usually imposed its will upon the technological field and not vice-versa. Indeed it was the technologists that would have to translate the qualitative characteristics of their innovative device into profit potential and that were obliged to accompany this primary innovation with a secondary innovation, i.e. with the fabrication of a new marketing strategy capable of convincing the private sector to invest in their project. And exactly because this was not an easy task, a new institutional innovation emerged within the technological field: the consortia of universities, the work of which was to create links between the private sector and the technology produced in their marine energy departments.

A second revelation of the data had to do with the observed divergence in the views of the interviewees regarding the appropriate way to fund technological innovations. Small-scale developers were quite sceptical towards what they called the 'quick-book' mentality of investors whereas people who worked in academia had to accept without great enthusiasm the fact that they had to address the needs and dictates of the private sector. On the other hand, the interviewee who worked in the least fragile niche of the field, i.e. in an investor's consortium, advocated that the intervention of the state to the development of the sector should be reduced to the minimum as if the market of marine

energy technology in Scotland could be described as perfectly competitive. Considering however, the absence of a public company charged with the duty of developing the sector of marine energy, and the fact that his consortium did not include only large corporations but also agencies of the Scottish public sector then this divergence was not at all surprising.

What I mean is that if the participation of the government in the development of the sector was reduced to the minimum, then the only potential source of funding for technological projects in the sector would be the corporations which participate in investor's consortia. Hence, such institutions would be easily able to monopolise the sector of marine energy technology. This contrasts the neoclassical argument that government intervention distorts the market because it hinders the beneficial effects of perfect competition and leads to suboptimal results (Mankiw, 2010). On the contrary it is the lack of government intervention that creates a monopoly or an oligopoly and hence leads to suboptimal results in the market. Under these circumstances, the sceptical stance of the more fragile interviewees was also predictable. Small developers could not possibly give their uninhibited support to an investing mentality that rendered their work more difficult. PhD students and people from academia were rightfully suspicious of an investing attitude that shelved a large number of their projects and ideas.

The participation of government agencies to the consortia of large investors signified the possibility that the large investors and their preferred innovating projects would in the end determine the way that the technology would develop in the future. Hence, it was possible to see that the views and mentalities of the radical creativity of the agents in the field depended on their position within the field. This divergence however, would be impossible to understand had it not been for the examination of the degree of dependence of the technological field from the private sector. And since the concept of radical creativity implies that the way people think has an impact on the personal and societal innovations they perform, it was not surprising that the rejection of their projects by the private sector had induced many fragile agents in the field to move beyond the mere expression of their negative feelings towards this status quo and to try to develop a new narrative. With regards to their respective location within the field, they were trying to increase their autonomy from the private sector. For example, a member of staff of one of the largest Scottish universities who specialised in technology policy claimed that the institutions involved in the development of marine energy, including the universities, developer firms and the public sector should try to impose to some extent their own agenda and digress from the dictates of the markets:

“It seemed pretty clear at that time that there were a lot of difficulties in the way the companies were being financed. That was dictating in many ways the kind of innovation dynamics that they were able to pursue. Things have changed quite a lot in the ways of our energy sector since 2007 but I'm not sure...I think in the lifetime of the marine sector, I think that's a rather short period, I think in the wider UK energy system we've seen a trend towards much more significant market intervention to try and respond to the kind of ambitions on policy. So, policy has become a lot more ambitious since 2007 in terms of the climate agenda and the renewables' deployment agenda. And also energy security has become a lot more significant concern. So, the wider institutions of the energy system are being remade. They have been substantially changed I think since 2007. I think, what's interesting is that if you compare the UK to other parts of Europe, we're still substantially oriented towards financial capital but relative to the way UK was five years ago, I think we've developed a more kind of institutionalist interventionist model.”

What this quote revealed is that there were agents of the field and the UK state who were aware of the ‘preferences’ of large investors of the private sector and attempted to stop the state from relying entirely on the invisible hand of the markets. They intervened to create alternate pathways of development of marine energy technology. This meant that the technological field had become more autonomous in relation to the markets but more dependent on the state, which influenced it using regulation and money. However the dependence on two different sources of funding meant that technologists within the field could sometimes act as a counterweight to the dictates of the former with the requests of the latter and thus, could be more autonomous.

This policy of the UK's authorities bore a lot of resemblance to the arguments of those who supported the need for government intervention in the case of infant industries. This support to the argument that infant industries (Lin and Chang, 2009) need the help and funding of the public sector to survive competition signified a retreat from extreme laissez faire ideologies such as monetarism (Friedman, 1962) or neoclassical economics (Lucas, 1976).

However, the quest for autonomy was not restricted to institutions related to the state. Small developer firms, unable to acquire funding from overaggressive investors of the private sector searched and found alternative ways to fund their projects. One such way was using the help of charity organisations such as Community Energy Scotland (2013) who transferred knowledge and funding from the Scottish government and local governments across Scotland to community owned renewable energy projects (BusinessGreen Staff, 2014). What such institutions had to offer was exactly an increased autonomy to small scale developers the projects of which needed more time to become profitable than the time required by quick book minded investors. Hence, in the frontier between the technological field and the markets, statutory intervention and alternative funding projects could provide to the field some autonomy in the technological trajectories it performed.

8.3 A Field Among Others

The frontier with the private sector is not the only one to which attention needs to be paid. The field of marine energy technology is nothing more than a sub-field to the technological field of energy production which is composed of many different engineering sub-fields such as the field of oil and gas and the wind energy field. The technological field forms uneasy relations with those other fields because in a world where resources are scarce, there is competition among firms and sectors.

This type of competition appeared in many interviews. A good example was the following extract from the interview of a leading member of a construction and repair company when asked about the problems of the marine energy sector:

“There are absolutely wide, strategic problems. The main one at the moment is definitely funding. Funding the development of devices by developers is very difficult. The private sector has put a certain amount of funding into wind which is obviously now becoming a more mature industry, offshore wind.”

Hence, mature industries tended to out-compete nascent industries in the search for funding from the private sector. This was because of the risk-averse characteristics of the investors, i.e. their tendency to prefer a

certain amount of money now than an uncertain amount of money in the future, even though they might have been of the same net present value (Nicholson and Snyder, 2008). This was congruent with the observation in the previous chapters that agents of nascent engineering fields had to be less risk-averse than their counterparts in mature engineering fields.

As would be expected within this performed dimension, the two similar and innovative fields of offshore wind and marine energy technology had to compete and mostly in terms of funding and personnel. However, the two fields shared many technical characteristics and university researchers for example could easily work for both fields, as can be seen in the following quote from a PhD student:

“At the moment I am a research associate. I have this post for three years now. So, in these three years I’ve worked for different projects, lasting, some short term and some a bit longer. The last one I had was three years. I’m looking at different problems and different solutions for marine energy and also wind energy.”

If the field of marine energy competed with the in some ways technically similar field of wind energy, it would be easy to imagine how fierce the competition might be with the field of oil and gas fossil fuels. In that case, the competition was quite intense in terms of personnel, because it was much more difficult to exchange workers as can be seen

in the following answer of a leading member of a construction and developing firm:

“And when I left the army, I took an engineering degree down in London. And my view was to get into the oil and gas subsea construction market. ... Well, there are very few oil and gas people in the renewables' markets and one reason being is that renewable energy is quite low intensity. ... And my point is that the value in oil and gas is such that it pays such high wages, so very few people get into the renewables. So, that's why there are not that many oil and gas people in the renewable industry right now. So, we think that, given our experience in, with our constructing experience, we've got something to offer.”

The interviewee thought that they could find opportunities in the market of renewable energy because there were similarities between this market and the oil and gas sector. Two similar fields can exchange information and people so that either one of them or both can benefit from this relationship. And it seems to me that it is the innovative fields that benefit the most from the experience of the already existing ones. The latter have already addressed many of the challenges that the new fields will have to solve. The migration of only a few people from the oil and gas sector to the marine energy field, due to the latter's low wages meant that the amount of knowledge transfer that took place was also limited, because know-how is linked to the people who have obtained it through experience. Hence, with only a few people moving to the marine energy

field, the tacit knowledge relevant to the field could not have been transmitted in its entirety (Collins, 2001; Polanyi, 1966).

At the same time it is not really clear what the already existing fields gain from the innovative. There is a possibility that the innovative fields will develop some new artefacts, processes and practices that will rejuvenate even century old technological fields, but this is uncertain and is probably more of a long-term effect. It could be argued that in the short-run, the only thing that already existing fields ‘gain’ from the emergence of new technologies is an increase in the level of competition they have to face. An example of the benefits new fields might gain from already existing ones was offered by the leading member of a marine measurement instruments’ developing firm who argued that the field of marine energy had a lot to learn from the oil and gas sector:

“Device failures are going to be a critical thing that this industry will have to overcome. There are a lot of restraints in the oil and gas industry, a lot of techniques in the oil and gas industry that this industry is not adopting. They've got to look more towards the oil and gas industry and learn from their mistakes in the '60s and '70s.”

The quote above confirmed that new fields could obtain know-how from the old. The similarities in the independent dimension of the two sectors (both oil and gas and marine energy technology had to deal with the complex environment of the ocean in the UK) meant that the challenges

that the marine energy field had to face at the moment this research was conducted was similar to the problems that the oil and gas industry solved during the '60s and '70s.

The problem however, was that frequently this knowledge transfer did not happen. For example, in the following quote the interviewee actually accused the field of marine energy technology of not taking into account the experience of the oil and gas sector:

“I think this industry is taking a particularly close-minded approach and is specifically avoiding the experiences of the oil and gas industry because it is so, non-green. But they've been producing oil from the ocean for a long time... And this industry can learn from their mistakes. And I do not believe that they are.”

Agents within the marine energy field may be sceptical towards acquiring experience or know-how from the fossil fuels' sectors field due to the existence of competition between the two sectors. The renewable energy fields had been created as substitutes to the fossil fuels' sector and competed with it for the necessary albeit scarce funding. This competition rendered them hostile towards any type of knowledge and intellectual products that were produced in the dirty, polluting and unsustainable fossil fuels field.

Additionally, another reason for this scepticism was the higher wages of the oil and gas sector which derived from the more mature state

of this industry. Higher wages mean that the renewable (and of course marine) energy sector was unable to attract agents who had successfully been active in the oil and gas sector. Hence, it was impossible to acquire all the tacit and non-tacit knowledge that these agents monopolised. Data from the interviews revealed that there were agents of the field who regarded as hostile not only other fields of energy production but in general all technological fields which were more established than the field of marine energy. For example a leading member of a small tidal turbine-producing firm argued that the field of marine energy had to compete with the field of computer software production and claimed that it was significantly easier to an investor to fund a software producing company than one that retrieved energy from the ocean:

“You know, if I am an investor and I have ten or one hundred million to invest I’ll do it where I’m going to get the best return from it. So, if I can put it into a dot com company that can...Basically you buy, you rent some rooms, you buy some computers and just fill them full of people. And you can quite quickly see whether something is going to work or not. That’s...where you are basically going to get your best return. If you want a longer term, you have to look at, well the government has to look at the whole picture and say ‘well, that’s good’ but probably, generally it will only create small companies that are highly geared and are primed to return in that time. If you want something that will create more jobs, more socio-economic impact and have a sticky industry that stays there and can’t just go up and go, then we have to pick the sectors where we want that to happen in and have to make sure that the incentives are there for investors, whether it will be for tax breaks... You wrote? I suppose I’m talking

about tax incentives to look at the longer terms, probably one of the easiest ways to do it.”

The technological field of software production had one major advantage over the field of marine energy. Installation and experimentation in the sector were much cheaper. On the other hand the interviewee mentioned the key advantage of the field of marine energy technology. It offered the opportunity to develop a ‘sticky’ industry due to the characteristics of the independent dimension in Scotland, i.e. the abundance of wave and tidal energy potential in its waters. Sticky industries are those technological fields in which investors cannot take their investments easily to another country. Hence, sticky industries offer jobs and profits for many years to come. Furthermore, it is interesting to note that this leading member claimed that the solution to this dead-end for the marine energy sector would be found only via the intervention of the government and measures such as regulation and taxation.

8.4 The Sceptics

Up to this point, I have focused mostly on the way the respondents described the interactions of the technological field with other *organisations*, i.e. with entities such as privately owned firms, public regulatory institutions and universities. However, the data

revealed that the interviewees considered these interactions as only the first type of influence that the rest of Scottish socio-technical reality exercised on the technological field of marine energy. Several interviewees referred to a second type of influence, an influence which they attributed to parts of the Scottish public who were suspicious towards technological development.

Even though the number and budget of engineering departments in Scotland would suggest that Scottish society holds technological development in high regard, there were interviewees who argued that, in late modern Scotland, there were people who did not always consider investments in technology as something beneficial. The respondents argued that these people had to be convinced in order to support investments to technology, especially from the public sector. For example, the leading member of a testing facility for marine energy devices argued that the society of UK had so far failed many times in developing innovative technological sectors mainly due to three reasons: the tendency of UK governments to encourage the development of the financial rather than technological sector, the competition from overseas (i.e. the effects of cheap labour being more easily available within the globalised economy) and, last but not least what he called the widespread conservatism of the people of the UK:

“I’ll say that we are quite conservative by nature as a nation. And you know, perhaps, there is too much of a focus in investments that are on banking and the finance sector. It is definitely valuable and it is right on the doorstep and it sounds very loudly, but on the engineering side maybe it’s also that the engineers are quite reckless and inward looking and they don’t shout loudly like the bankers and they don’t make their cases right. But you know, also the competition from overseas. You know, cheap labour, cheap and good labour from overseas. You’re looking...Many years ago ‘made in Taiwan’ used to be a derogatory kind of term but now it’s one of the best things in the world to be made in Taiwan or China, or Japan, or Chile. So, there are lots of those places that they out-competed the UK because it wasn’t prepared probably to invest in longer term and be less cautious.”

If the two first causes of UK’s inefficient support of innovative technological sectors could be analysed according to the argumentation of the previous sections of this chapter, the conservatism of the people of the UK however was an argument of a radically different nature. It demonstrated how the high degree of uncertainty related to the undertaking of technological innovation required a leap of faith to support it. And, according to the interviewee, not everyone was equally prone to perform this leap of faith.

The issue about the lack of support to technology was raised by other interviewees, such as the leading member of a small developer firm, who not only mentioned the problem but also offered an explanation of its origins:

“To be quite blunt, I think it comes from Thatcher isn’t it? I think it’s a post war...It’s not just Thatcher, but, but she may be a...she maintained it, it’s a post war, in the UK after the war there is just this, there is just a move to get away from industrialisation because it seems all dirty and there has been an overreliance on the financial sector in this country. The country just does not take a long term view in terms of investment. It has, it looks in a three to five year horizon rather than may be a five to ten or even fifteen year horizon in developing technologies and an industry. It’s very, very quick; it’s a quick book mentality.”

The interviewee suggested that politicians like Margaret Thatcher exercised a huge amount of influence to the views of the public; and also that he did not consider Thatcherism’s approach to technological innovation a break from the previous paradigm of the economy of the UK, based on the policies of Clement Atlee (see for example Mathijs, 2011), but rather a continuation of it. He argued that both paradigms resented it because it, from his point of view, ‘seemed all dirty’ and instead promoted the financial sector.

Following a similar rationale, the leading member of a testing facility declared that, even though the human and natural resources that the sector of marine energy technology needed could be found in the UK, the development of the sector was in danger due to the lack of confidence to invest, the inefficient commercialisation of the devices and the absence of a correct investment approach and support mechanisms which existed in other countries.

“We've got 25% of the tidal resource of the whole of Europe. 10% of Europe's wave resource. There's no problem on that side. We've got a lot of exciting people with good ideas. There are a lot of new ideas and new devices for deployment to come. I think it is putting those devices to commercial scale and into commercialisation which is the challenge. And typically in the UK we've been quite rubbish at that historically. UK has led a lot of engineering research and we lost the lead giving it over to other countries and other nations that have been able to run with it by having a different investment approach or a different support mechanism all of which have made a more successful industry. The commercialisation and the confidence to invest, that's the thing that in the UK perhaps has been lacking in the past in multiple industries and let's hope that we will not face this problem in the marine industry as well.”

The interviewee claimed that the UK had been surpassed in many technological sectors by other nations because it failed to apply specific institutional innovations and instead maintained outdated and inefficient investment approaches and support mechanisms based on the absolute predominance of the private sector. His view is an excellent example of the importance of institutional innovations to technological development. The interviewees claimed that, without these innovations, technological development was impossible even if there could be found all the necessary natural and human resources.

If the argument of the last two quotes was that there was widespread scepticism towards innovation in engineering specifically in the UK, the following interviewee argued that this was a much more

common phenomenon. The leading member of a construction and developing company argued that, in general, people in late modern societies had been alienated from their own creations and took for granted their existence of technological entities:

“So, I don't know, I think we kind of lose sight with all this technology above us. We lose sight of these things and the plane is late because it's snowing and everyone's annoyed because the planes aren't flying. But they're not flying because Mother Nature has put some hazardous conditions out there and you could die. But people don't think like that anymore, they just think ‘Why it's my plane late?’ you know, ‘Why can't I fly with all the snow?’... I think there's a disconnect with all this technology.”

This interviewee argued that often people considered technology as something given and they neither recognised how important it was for the shaping of their future nor how difficult it was to produce and work with it.

The fact that a university engineering department chose to form a group of staff and students the purpose of which was to present in a more constant and coherent way the results of the research that took place in the department to the media and ultimately to the public, was another hint that investments in technology were not always popular. This group was certainly an institutional innovation and institutional innovations tended to appear to solve an existing problem. When asked why this

institutional innovation was necessary, a member of such a team, a PhD in engineering student responded in the following way:

“Well, there are a number of reasons. The most obvious one is that a lot of this research is actually funded by the general public... This means, if we can convince them that the research is interesting and useful, then, it's easier for us to justify asking for more funds. So, that's one, sort of pragmatic reason... I think that the general public who's not necessarily exposed to research, doesn't necessarily understand, how difficult it is, for example, to develop a product, how much time it takes and, and the stages... And the bigger and more complicated the technology is, the more time is spent in development and so, I think it's important for the public to be aware that there are these things going on and that we need to continue researching topics, we need to continue learning more about things in order to have something in the future.”

Even so, this interviewee did not argue that the public was hostile towards technological development. She did not reject however the idea that this exaggeration bore some seeds of truth:

“I wouldn't go as far as saying hostile. I think that, in part, research is very, very expensive and sometimes years of research don't really lead to something concrete... So, obviously, for the public, it probably feels like quite a high burden to say that we're going to spend 20 million in this and then if we fail it's not even going to be practical.”

The interviewee confirmed the hypothesis that there were people in Scotland who did not always consider technological development

beneficial. Hence, technologists had to develop a narrative that would convince these people that technologically innovative fields were worth the investment they received. Now, this stance towards technology is very different from 19th century views. Hughes (2004) listed a number of writers who maintained the belief that the development of science and technology should always be pursued because it solved more problems than those that it created. It seemed that the interviewees considered that this modernist belief was not as predominant in as in the past.

During the latter half of the 20th century, the engineering sectors have been hit by a wave of de-industrialisation. De-industrialisation was analysed by economists (see for example, Krugman, 1996) and Marxist theorists. The latter have described changes and phenomena in the production process that have the potential to induce this phenomenon such as for example the financialization of the economy (Harvey, 2005) and the emergence of neofordism (Aglietta, 1976). These respondents' view that there was widespread scepticism towards technological innovation in the engineering fields might be related to the way they perceived these phenomena. It is important to remember that within the wider socio-technical reality, the field of marine energy technology competes for resources with other social loci. Hence, it would not be far-fetched to argue that the interviewees felt the need to make sure that their

field would not lose its funding due to another wave of de-industrialisation or to the further financialization of the economy.

Finally, the environmental concerns as expressed by the principles and function of public institutions as well as by the answers of the interviewees in Chapter 6 of this thesis hindered even more the predominance of the idea that technological change was always considered something desirable, even among the theorists of technology who have called for its democratisation (Serres, 2009). The absence of the latter, namely a democratic deficit could be one more reason for the lack of support of innovative technological projects on behalf of the public (Bell et al., 2013).

8.5 Summary

This chapter aimed to examine the frontiers of the field of marine energy technology, i.e. to investigate the way it interacts with other socio-technical loci, such as the financial field, the general public and other fields, similar or different. I think that at this moment it is possible to present how the technological field constitutes itself as a socio-technical locus with distinct targets that is nevertheless both similar and different to other socio-technical loci.

As I showed in the previous chapters, the basis of the formation of a new technological (sub) field was the complexity of the independent dimension. It was the elements of the independent dimension that obliged humans to create new technological artefacts and to develop new skills each time they wanted to satisfy a new need. The technological field of marine energy emerged because the greater complexity of the oceanic environment meant that the skills for developing wind energy technology were not sufficient for the exploitation of this new type of energy.

As soon as some technologists recognised the need to develop new artefacts and skills, they started developing some research projects to achieve that. The realisation of these projects, however, needed funding. And in late modern societies the majority of the funding comes from the private sector. However, not all projects got the funding they desired from the markets. Large investors created consortia to monopolise the technological sector and to develop the types of technology they preferred, i.e. those that produced large returns in a few years. Other research projects were rejected and hence, the agents of the field of marine energy who proposed them became more sceptical towards the financing from the private sector. To avoid the shelving of their ideas they sought alternate types of funding, such as funding from the public sector or from communities and charity organisations.

These developers had to advertise their research, even more so, since they believed that there were parts of the Scottish public who were sceptical towards technological development. Even though they dominated their technological field, the large investors and developers had to advertise their research because they still had to out-compete other technological fields. The latter could affect the field not only via competition but also via the exchange of knowledge and personnel, elements which could be described as forms of cultural capital. This type of capital determined the structure and organisation of the technological field and hence, the paths that the development of technology might follow. What that means is that they determined the *internal characteristics* of the field. Without knowing the internal characteristics of the field, the answer to the institutional questions would remain forever incomplete. The analysis of these characteristics will be the theme of the next chapter.

Chapter 9: The Internal Characteristics of the Technological Field

This chapter will build upon the findings of Chapter 8 to analyse the ways in which the technological field utilised the resources and constraints it inherited from the rest of socio-technical reality to build its own rules and resources. These rules and resources are internal characteristics of the field that rendered it capable of overcoming any hurdles the independent dimension put in the construction of new innovative technological artefacts. The description of these internal characteristics of the field is an essential part of the answer to question four, i.e. the institutional question.

The field shares similarities with other fields of renewable energy because the former emerged as a sub-field of the greater field of renewable energy which itself was a 'child' of the field of energy production. Hence, the participants in the technological field of marine energy technology inherited the need to re-invent and apply aspects of the material and non-material culture of modern societies which were vital to the survival of any technological sub-field within such a complex socio-technical reality. Simultaneously, however, the agents of the field encountered elements of the independent dimension, which were unique to the field and justified its creation as a subfield (Bourdieu and

Wacquant, 1992) of the field of renewable energy. The interaction with these elements dictated the instituting of rules and resources with innovative characteristics which were now a prerequisite for any potential realisation of successful technological innovations. The internal characteristics of the field obliged the agents therein to apply specific sets of behavioural patterns. Agents who did not utilise these behavioural patterns were destined to fail and to exit the field.

This chapter is ordered into four parts. The first part describes the technological field as a bureaucratic social locus. Furthermore, since the unique characteristics of the technological field consist of two types of sets of behavioural patterns, which the agents developed within the field, namely the bureaucratic and the technological capital, parts two and three of this chapter are dedicated to the description of these two types of capital. They are both sets of behavioural patterns which the agents developed in a more and more complex form as they learned and innovated within the field. Following the rationale of Bourdieu (2001), I will argue that their distribution and features determined to a large extent the development of the technological field of marine energy. The remaining part of this chapter will discuss how and when these two types of resources contradicted each other and what that meant for the technological innovations that took place in the field.

9.1 Cultural Capital

The technological field of marine energy emerged after several centuries of the development of modern societies, two key features of which were the imposition of the model of the bureaucratic, specialised institution (Weber, 1905) and their continuous expansion which was due to their greater productive and military capability. The latter was achieved via the continuous generation and accumulation of technological innovation. Hence, there is a relation between bureaucratisation and innovation in modern societies. Hall (1963) describes the key characteristics of a bureaucratic organisation in the following way:

- “1. A division of labor based upon functional specialization
2. A well-defined hierarchy of authority
3. A system of rules covering the rights and duties of positional incumbents
4. A system of procedures for dealing with work situations
5. Impersonality of interpersonal relations
6. Promotion and selection for employment based upon technical competence.” (Hall, 1963, p. 33)

These characteristics were found in the answers of the interviewees about the internal organisation of the technological field. Even before the interviews, during the first stage of the research, it was possible to observe that the field of marine energy technology is a specialised

bureaucratic institution that included a number of other institutions that were even more specialised in specific types of labour.

During the interviews however, I gathered data related to the importance of the division of labour within the institutions of the field. Most interviewees argued that the separation of duties and specialisation was an enabling instrument, as long as it did not signify the absence of teamwork and was not too restrictive, in the sense that it could be breached when it failed, as suggested by the following quote from a member of the public sector:

“I think having separate responsibilities is important. In terms of what people do, structuring their responsibilities is necessary but they have to work by sharing information and communication. You know, some organisations can be more complex than they need to be. That is why you must have clear, very clear definitions of what people do even though sometimes they will have to break through these barriers.”

The division of labour was a characteristic that the field of marine energy shared not only with other technological fields but also with many other socio-technical loci, such as for example the financial sector. However, the uniqueness of the field of marine energy became apparent as soon as I searched for the other five characteristics of bureaucratic organisations in the responses. The hierarchy of authority, the rules covering the rights and duties of the agents in the field, the system of procedure for dealing

with work situations and the meritocratic system of promotion and regulation in the field were determined by the amount of two types of cultural capital possessed by each agent in the field. I have named the two types of cultural capital bureaucratic and technological capital.

Cultural capital is a concept developed by Bourdieu which describes those non-economic resources which are internalised by agents through the habitus and accumulate over time within a given field. The existence of these resources reveals the impact of each field's history because the behaviour of the agents therein is determined by the amounts of capital that they accumulated in the past (Bourdieu, 1986). Agents of fields encounter and accumulate three types of cultural capital, as described by Bourdieu:

“Cultural capital can exist in three forms: in the embodied state, i.e., in the form of long-lasting dispositions of the mind and body; in the objectified state, in the form of cultural goods (pictures, books, dictionaries, instruments, machines, etc.), which are the trace or realization of theories or critiques of these theories, problematics, etc.; and in the institutionalized state, a form of objectification which must be set apart because, as will be seen in the case of educational qualifications, it confers entirely original properties on the cultural capital which it is presumed to guarantee.” (Bourdieu, 1986, p.282)

Embodied cultural capital refers to all those dispositions which the agents have internalised inside a given field to an extent that determines their behaviour in the regulated struggle that takes place therein.

Objectified cultural capital refers to all these material goods which can either be used to accumulate embodied cultural capital or function as proof of its existence. Institutionalised cultural capital is also found in material form but, unlike objectified cultural capital, it is used to distinguish those who possess it from those who do not. An example of institutionalised cultural capital is the use of the title of a PhD. It distinguishes those who possess it from those who have not made an original contribution to science. Furthermore, it is important to remember that cultural capital can be transformed into economic capital. In fact Bourdieu (1986) argues that the existence of cultural capitals is a prerequisite for the appropriation and use of economic capital in modern societies.

Since it could be derived from the analysis of the data, I decided to maintain the concept of cultural capital (unlike the concept of the habitus) because it is a fundamental characteristic of fields. Only the existence of specific types of resources renders meaningful the use of the concept of the field as a description of an instituted social space of interactions between competing and collaborating institutions. However, since this analysis is not Bourdieuan, the bureaucratic and technological types of cultural capital observed in the field of marine energy technology diverged from their Bourdieuan counterparts.

Bourdieuian cultural capital refers to non-economic resources which are internalised through the habitus. The types of cultural capital which I describe in the following pages consist of sets of behavioural patterns and information that the agents acquired reflexively during their participation in the field of marine energy technology. The agents of the technological field of marine energy had to learn and utilise specific sets of behavioural patterns which were useful only within this technological field. Success in a technological field required an efficient knowledge of these sets of behavioural patterns and not only the ones which corresponded to a specific position in the field. It is necessary to know to some extent those which corresponded to all the other positions. That way it would be possible to interact more efficiently with agents in other positions. Since these sets of behavioural patterns were developed through personal or societal innovations, they could be accumulated. Hence, it made sense to talk about forms of capital i.e. internalised behavioural resources which promoted an agent's interests within the field.

9.2 Bureaucratic capital

Bureaucratic capital was observed in the responses to many different questions and especially those given to a question asking them

to define the key ingredients of success in their employment. To succeed, agents in the field instituted a working ethos, founded upon specific types of knowledge. This ethos was used as a type of 'glue' that facilitated the coordination of the various specialised loci and niches within the institutions of the field. An example of the characteristics of this working ethos can be seen in the following extract from the interview of a member of the periphery of the field:

"I think we should work as a team. But, within that team, everyone should have their own responsibilities. For example, I want to work with other people for a project, but I don't want anyone to be involved to my project and try to do things that I have to do. And of course, I wouldn't do the same to someone else."

The interviewee mentioned that teamwork and respect for the division of labour were key ingredients of success in a company. Efficient teamwork and respect in the division of labour were key ingredients of a wider set of sets of behavioural patterns which rendered the agents who possessed them capable of maintaining a good professional relationship. Beyond these two characteristics, a good professional relationship was described as one where all the related agents possessed a sufficient amount of knowledge about their partners, their capabilities and their fears and desires; so that they could achieve the goals they had set together.

This was obvious in the following quote from a PhD student who described his relationship with his supervisor and colleagues:

“A good relation with others is important. Well, knowing also the limitations of your colleagues and my colleagues also to know my limitations. So that they know what you are going to be able to do. That's one of the main keys. And trying to have a good communication between us. So, knowing at each time, what each of us is doing, so we won't overlap. And that's also very important with the supervisor. I mean the supervisor must know what you are doing and anyone so that you're not going in wrong direction, because of a lack of supervision. So these are the key ingredients.”

The sets of behavioural patterns which helped the agents of the field maintain ‘good professional’ relationships affected the behaviour of the agents in the field and obliged them to use specific types of discussion, such as jokes, and avoiding being rude, as can be seen in the following quote from a research associate from a university engineering department:

“I think that first of all one of the key ingredients for a good collaboration is personal relationship. So, when you have to collaborate with someone, I personally think you have to have a good relationship with him and you have to like working with them and enjoy their company. So, if you are sort of unpleasant to someone or rude to them or you do not make an effort to have a coffee, or chat, or lunch or something like that and that, that's not good. So, I think one key ingredient to good collaboration is making an effort to build that relationship. So, you know, that sort

of personal relationship, ask them what the weather is, tell them a joke or something.”

Here, the research associate claimed that there were types of behaviour (e.g. telling a joke) which helped develop an effective professional relationship and types of behaviour who ruined it (e.g. being rude). The most interesting point here is that these sets of behavioural patterns were not necessarily related to their object of work. Telling jokes and being polite were two behavioural patterns, designed to deal with people, which could be applied to any sector of the economy. Furthermore, the interviewee reflexively understood that these behavioural patterns were used to promote a different aim, i.e. the successful collaboration between agents in his institution.

The sets of behavioural patterns associated with bureaucratic capital, described so far, do not resemble Bourdieu's (1986) institutionalised cultural capital. Even though they were easily described, they were not determined by specific institutions, in the sense that no institution in the field developed rules about how to chat and exchange jokes. However, there were sets of behavioural patterns which had to respect some very specific rules developed by specific institutions. For example, even though respect in the division of labour within an institution was not a rule officially sanctioned by the institution, the division of labour per se was frequently determined by the leading

members of each institution, as can be seen in the following quote from a leading member of a public institution:

“Because that's the way in which we are supposed to organise the staff. The staff has formal job descriptions and they should be able to understand at the beginning of the year what they are going to be asked to deliver by the end of the year...”

Here, the interviewee explained that each member of the public institution had a formal job description. Hence, the institution had already decided what tasks the workers had to complete ‘by the end of the year’ and employees had to respect this job description and tried to learn the ways to achieve what their job entailed.

In several institutions of the field the process of completing specific tasks was formalised to such an extent that it could be described as a system, an obligatory procedure, a map or a protocol, as can be seen in the following quote from a member of a testing facility:

“That is quite easy in that we have an integrated management system here, that we developed as a quality system for managing health and safety, environmental and quality matters and all the different actions that we take. And we have standard obligatory procedures which we follow. So, for example at my own job when it comes to a client who initially registered and brought their machines for testing at (name of testing facility), we have a process map that sets out what information we need at what stage of the relationship in order to progress to the next stage. And all is well defined within our management system.”

Hence, it would be misleading to describe bureaucratic capital as a type of cultural capital that included only non-standardised sets of behavioural patterns. There were also a number of standardised sets of behavioural patterns that agents of the field had to learn to be successful in their work.

Even so, the interviewees emphasised more the non-standardised aspects of bureaucratic capital. The majority mentioned that flexibility, defined as the capability to handle many different work situations was a key ingredient of success in the field. For example, flexibility was the first key ingredient of success cited by a member of a testing facility, an organisation that was obliged to communicate and listen to the requests of the developers whose devices it tested:

“I think our ability to be flexible and to be supportive to the client's own project that we facilitate here is the key to success. Because in truth we have to be fast paced, because each company we work with is really different, we work with everything, from a very small company to have developed an idea themselves to larger companies who have a large number of industrial partners to help them with their project to companies who have been bought by large liaisons or utility companies. So, the ability to be flexible and respond differently to the clients' attending on how they'd like to work.”

The word flexibility referred to the capability to cope with any unpredictable challenges posed by the complexity of socio-technical

reality, i.e. the need to test very different devices which had been invented and fabricated by equally distinct developer firms. This complexity was encountered to such an extent in this specific niche of the field because closure (Pinch and Bijker, 1984) had not been achieved in the tidal energy sector and even less so in the wave sector. There was no standardised model of marine energy device which would have been followed by every developer. Testing facilities had to cope with the handling of devices that used distinct technologies instead of just evaluating slightly different versions of the same basic technological artefact.

Furthermore, the interviewee mentioned that flexibility was a key ingredient of a successful collaboration with other institutions in the field of marine energy. Maintaining such collaborations was another important set of behavioural patterns of bureaucratic capital. In many positions of the field, creating links and collaborating with people from other institutions was the key to success. In research institutions, the capability to communicate effectively with people from the industry could be the critical factor for the realisation of an innovative project, as a PhD student argued:

“I think that’s the thing now, in order to be a successful researcher you have to be also very successful in marketing your research, you know.”

Inter-organisational collaboration and networking was in fact so important to the institutions of the field that some decided to hire people whose job was to serve as links between different types of institutions.

To be more precise, a consortium of universities hired people whose job was to approach private firms and inform them about the research conducted in these universities, as can be seen in the following quote:

“And this is why I love the job, I go and check academics, find out what they're up to, find out what their expertise is, find out what they're interested in... The second part of my job is to go and find the companies. So, I find the companies working in marine energy and this covers a whole range of companies. So, I talk to all of these companies and find out what they need, where they are going to get in their expertise. And because I'm speaking to the academics as well, basically I'm a facilitator. I go and find out what people need and I put people in a room together and see what happens.”

Here the interviewee described himself as a link who aimed to facilitate the formation of such collaborations. Hence, his position within the field could be described as an institutional innovation that aimed to improve the amount of bureaucratic capital of the universities which participated in this consortium. By employing people like him, the consortium of universities would manage to have in its service people specialised in knowing how to deal with firms of the private sector and hence, would increase its bureaucratic capital.

So far, I have established that the bureaucratic capital of the field of marine energy technology was a key ingredient of success therein. To be able to call these sets of behavioural patterns a form of cultural capital however, I had to show that they could be pursued and accumulated by the agents of the field. A first hint about that was that (when asked about the key ingredients of success in his position within the field) a leading member of a testing facility linked the capability of being flexible with the experience of working within specific types of institutions:

“Adaptability, flexibility and I think a breadth of skills. A breadth of skills and experience. Quite often we are near new areas that have not been travelled before and so, some experience of traveling the uncharted path helps when you are in this situation. Also coming from a commercial degree in university makes quite a change in some professionalism and attitude, it's useful as well.”

What is of great importance, is the last sentence in this quote where the member of the testing facility links professionalism, i.e. the capability to maintain a good professional relationship with the acquisition of a commercial degree in a university. This meant that some of the sets of behavioural patterns associated with bureaucratic capital could be taught. To talk in Bourdieuan terms, a commercial degree in a university is a form of institutionalised cultural capital, a piece of paper that separated those who possessed specific types of sets of behavioural patterns from those who did not. Hence, the sets of behavioural patterns which

constituted bureaucratic capital consisted largely of knowledge which agents could learn.

The following quote from the interview of a PhD student confirmed that the experience of working in a specific position in the field increased what he called ‘the knowledge of the system’:

“I guess the easiest thing for me was, because...I’ve been here for so long, so therefore I know a lot of the staff and...because I know the University well, so there is no settling period if you know what I mean, you don’t need time to find an item, you don’t need time to know how the system works and who I get.”

The interviewee argued that in his position in the field there was necessarily a ‘settling period’. Time had to pass before a PhD student would be able to get used to the interactions with specific people in the university. The fact that he continued to work in the same institution for a long period of time, meant that he did not need time to settle.

Another characteristic of bureaucratic capital was that each of the distinct niches in the field required a more or less different utilisation of the capital that was available to the agents there. The hierarchy of the agents in the institutions of the field partially depended on the quantity and qualitative characteristics of the bureaucratic capital they had acquired during their participation in the field. The most prominent difference could be found between the niches which could be described

as positions with directorial duties on the one hand and the niches occupied by people who did not take strategic decisions about the policies of their institutions on the other. It was apparent in the interviews that more flexible agents who dealt with more diverse and distinct problems were active in higher positions in the hierarchy and took strategic decisions. Their working position was less standardised and even though they had to respect specific rules, they emphasised much more the innovative aspects of their work. One of the best descriptions of this effect was made by the leading member of a public institution:

“Difficult one for me because I've got a lot of freedom and I am one of the leading members of the team. Means I'm relatively autonomous. Which means that I have the opportunity to make the decisions in relation to the business as it rises to horizons gone, to listen to what ministers have got to say, to talk across the board, both within the organisation, within the Scottish Government and the UK and then take into account whether I see good practice, bad practice, better opportunities to take that into account and be able to shape and move things. So I think I'm lucky because that could be innovative, because I've got that facility within my day to day expectations in the job I do. Of course, it's also important, you're going to have to tell that there is a degree of instruction as well because once you've done your horizon planning and being innovative, you've got to fit that into the regulatory role which then becomes guidelines, instructions, requirements.”

The leading member of this institution had a significant amount of freedom to make his own choices on the one hand, even though he was in the end obliged to adapt his initiatives to a minimum of pre-existing bureaucratic protocols. This was quite different from the experience of PhD students who had to pursue research projects pre-decided by their supervisors, as explained in previous chapters.

It differed also from the following view of a non-leading member of a statutory institution who claimed that there was a shortage of innovation within his institution:

“I think that innovation is a key aspect of this role. I don't necessarily think it's a key aspect of the civil service. I think the civil service is relying a lot on instruction and less on innovation. I think if you go out without your instructions, go out with your instructed role, it can cause ruptures within the team. And I think that's, that's probably an institutional change that is required across (name of public institution) and across the Scottish Government as a whole.”

The interviewee claimed that there was a rigid system of rules and instructions in the public sector that the workers had to follow. The emphasis was not on flexibility and innovation but on compliance to specific rules. The main reason why non-leading members of the public sector observed insufficient amounts of innovation in its function (something that was not observed in the answers of non-leading members of private firms) could be the over-expansion of the state's

responsibilities within modern societies and its incapability to develop new sets of behavioural patterns for each new locus of social activity. The reason why the state was unable to develop new sets of behavioural patterns for each new technological sector was that within modern societies, it is a reflection of a delicate distribution of political power among different social forces (Poulantzas, 1978). So, it is the logistics of the maintenance of this balancing distribution that oblige the state to apply to every new sector more or less similar sets of behavioural patterns and the reason why the state has not managed to adapt to game keeping capitalism (Bauman, 2000). Hence, there was a danger of allowing for insufficient amounts of innovative activity to the public sector's employees, until the development of suitable sets of behavioural patterns.

Even though the bureaucratic capital of the agents of the field who worked in private institutions encouraged them to be flexible, a number of interviewees argued that the necessary sets of behavioural patterns for working efficiently in the field, both formal and informal, had not developed enough. The absence of the necessary rules, practices and infrastructure and the need to invent them was something observed by many interviewees. An engineer of a private distributing company explained that she had to be innovative because the instructions for her job had not been developed yet:

“No. I don't have to follow instructions and not because I decided that on my own. As I said, it's a new position for this company. I and my managers are trying to make instructions at the moment. So we have left most of the projects on me. So the only instructions that I have to follow are time limits. So if I find a new product, let's say for example a new filtration system for work equipment they say to me OK, it's a good idea. We need a presentation from you for the whole project including margin sales, marketing, and any benefits for us in about a month. So I have to prepare everything in about a month. But how I am going to prepare this, there are no instructions.”

The interviewee claimed that her responsibilities were only vaguely defined by her institution. The newness of her position meant that it was her and her managers that tried to develop working instructions while she was trying to do her job.

The existence of bureaucratic capital, as described by the interviewees, justified the characterisation of the field as a bureaucratic social locus, as defined by Hall (1963). Indeed, the distribution of the bureaucratic capital in the field was among the determining factors of the hierarchy in the field. Agents active in lower positions tended to possess less amounts of bureaucratic capital and their bureaucratic capital included more standardised sets of behavioural patterns. The reverse was true for agents up in the organisational hierarchy. Furthermore, both standardised and non-standardised sets of behavioural patterns of bureaucratic capital offered instructions to the agents of the

field about how to deal with various work situations. Finally, even though some of the behavioural patterns could be used to develop a personal relationship among agents in various positions in the field, these relationships were understood as part of working within the field, and they were pursued without taking into account the personality of those involved.

Moreover, the type of bureaucratic capital that the interviewees described shared some similarities with cultural capital as defined by Bourdieu (1986). Some of the standardised sets of behavioural patterns of bureaucratic capital were quite similar to Bourdieu's (1986) institutionalised cultural capital. For example, graduates of commercial degrees were required to know how to interact with other agents in a professional environment. Their degree served as a sign that they had already obtained those sets of behavioural patterns. On the other hand, however, the bureaucratic capital described in this thesis differed from its Bourdieuan counterpart when its embodied form is taken under consideration. Bourdieu (1997) described a form of bureaucratic cultural capital whilst discussing the scientific field. Bureaucratic capital was described as a resource used by agents in the field to out-compete other agents and gather more bureaucratic and scientific capital (scientific capital was the second type of cultural capital that Bourdieu attributed to the scientific field). For example, professors can use their bureaucratic

capital, i.e. their position in the hierarchy of the university, to influence promotions and funding issues. Bureaucratic capital is frequently a source of heteronomy for the scientific field, i.e. it is a way for other social loci such as the private sector to influence the development of the scientific field.

In the case of the technological field described in this thesis, the interviewees emphasised much more the function of the sets of behavioural patterns associated with bureaucratic capital as a method to collaborate with other agents in the same institution or technological field in general. They used bureaucratic capital to handle the diverse and distinct types of challenges they would encounter within the technological field. In fact, these aspects of bureaucratic cultural capital as described by the interviewees are quite similar to Bourdieu's (1986) social capital. Bourdieu defined social capital as a resource which was generated as soon as a specific network formed and was related to the amounts of cultural capital each of the linked agents possessed. This was also true for the case of the technological field of marine energy. Bureaucratic capital was used to create links between agents of the field in order for them to be able to help each other in various ways and promote their interests. However, while Bourdieu (1986) argued that social capital was developed consciously or unconsciously by specific agents to join a group, bureaucratic capital was a resource which was

applied reflexively by the agents of the field of marine energy technology and not as an instrument for entering a specific group. The agents reflexively used it as a way to achieve other ends.

9.3 Technological capital

Beyond bureaucratic capital, the data from the interviews allowed me to recognise the existence of sets of behavioural patterns and types of knowledge that comprised another kind of cultural capital, technological capital. This form of capital referred to the capability of an agent (and of his or her institution) to successfully construct and complete technological entities (artefacts or processes) which functioned without problems.

The existence of such a type of capital was acknowledged by the interviewees themselves, as can be seen in the following quote from a leading member of a small developer firm:

“I suppose there’s two parts of it [the tidal energy device]. You’ve got the business part of it. The business philosophy is about community ownership and communities gaining the benefits from renewables, so, big part of it is, there’s there no other type of tidal technology company that we know of in the world in fact that are looking at tidal energy as a solution for regeneration and making sure that it’s the communities that live near these tidal resources that benefit from them. So, that’s the business part of it. In terms of the

technology, the thing that makes it most important well, we've taken off as a full systems integration approach to it and it's not going to be a one particular part that makes or breaks a technology, it's going to be everything, from deployment, operation, maintenance, actual system design. ”

The respondent argued that success in his niche of the field of marine energy technology depended on the co-existence of two prerequisites. The first was a new business model, which, in his case, meant to engage with community-led development of marine energy technology, i.e. an institutional innovation which led to the development of new types of bureaucratic capital. The second was a new model for the construction of marine energy devices, which he called ‘full systems integration approach’. This was not a new type of interaction with other agents of the field, but rather a new type of handling the elements of the independent dimension that comprised marine energy devices. The capability to develop these new and effective types of interaction was a key resource for agents active in specific positions in the field, such as developer firms.

Of course, the capability to develop new types of artefacts or processes did not necessarily mean that they would be accepted by its institutions and incorporated in the performed dimension. That depended on a set of criteria which the institutions of the field developed according to the nature of their interactions with the independent dimension, the

ways they interacted within the field, their interactions with other socio-technical loci and, last but not least, the history of the field. The leading member of the small developer firm offered an example of such criteria:

“Well, we were drawing up our specification four and a half years ago; the two overriding drivers for the technology are reliability and lifetime pence per kilowatt hour. So those are the two things that are going to make a technology work. Those are the driving forces. There’s a lot of other things that commend to it in terms of, you know, we can start talking about efficiencies, we can talk about consenting and safety and all these other things, but if those two basic criteria are not there, then your system, your technology, your tidal technology solution is not going to win, is not going to be, is not going to come out as a success.”

Among the criteria which determined which innovations could be considered successful, reliability and lifetime pence per kilowatt hour were the most important. Not surprisingly, this view was shared by other interviewees of the core of the field and by a university research associate:

“I think at the moment the cost of producing energy from wave and tidal devices is still very high. We need to bring that down over time. You know, if we want, if we want to see some significant deployments at sea in Scotland and elsewhere we need to bring the cost of energy down from this technology so that it is more cost competitive with other forms of generation and we need to provide secure energy supply in terms of energy security, we need to provide low carbon energy and we need to provide an affordable price.”

This respondent claimed that it was the capability to overcome both the hurdles of the independent (in this case energy security in the complex oceanic environment) and of the performed (in this case the cost) dimensions that made the technologists of a developer firm successful in the technological field. Technological innovation could not be defined as simply the creation of a new artefact. This artefact also had to abide by the criteria of the performed dimension of the field.

Overcoming the hurdles of the independent and the performed dimensions was possible only after the acquisition of specific types of sets of behavioural patterns, i.e., the acquisition of technological capital. The data revealed that there were three ways to gain technological capital. Education was the first: the capability to accumulate knowledge related to the construction of specific types of technological entities was something that could be taught in a number of institutions, prominent among which is the university, as the following PhD student explained when he discussed what helped him enter the field:

“My previous academic environment helped me to develop a good research background. So, this was necessary for my PhD research and also for the programmes that I am now using. It was easy for me to adapt to this new environment and to adapt to this new technological research based on the knowledge I had already gained from my previous studies.”

Even though the above quote might seem to reveal something trivial, a more detailed analysis demonstrates that it is far from straightforward. The interviewee did not cite specific domains of knowledge with which he was made familiar during his studies, but instead preferred to mention the obscure and ambiguous term of ‘research background’. Thanks to his research background he managed to adapt without problems to life in the field. I would definitely argue that studying in a university offered something more than knowledge about specific types of engineering. It provided the opportunity to learn the sets of behavioural patterns of conducting research and applying specific instruments, such as computer software packages to achieve specific research targets.

These sets of behavioural patterns could be described as a culture (which developed while one studied) or as a research associate of a University responded when asked about how his past employment and education helped him, a mind-set:

“So I think those two things, my scientific background, coupled with my sort of commercial awareness and policy awareness, that mind-set is quite useful to me now where I work.”

Here, the research associate repeated the distinction between bureaucratic and technological knowledge, as well as bureaucratic and

technological sets of behavioural patterns, by separating what he called ‘scientific background’ from his ‘commercial and policy awareness’.

On the other hand, the research associate did not distinguish between the technological and the scientific sets of behavioural patterns, which were described by Bourdieu (2001) as a ‘resident’ of scientific fields. This however did not mean that technological and scientific capitals were identical. Other interviewees who worked in the core of the technological field and not in universities such as the leading member of a small developer firm disagreed and when I referred to them as scientists, they spontaneously protested and declared that:

“I’m an engineer; I would never call myself a scientist...
I’m a businessman and engineer.”

The approach of the technological field can explain these diverging responses. The research associate worked in a university, an institution which aimed to develop both scientific (e.g. the laws of the independent dimension) and technological (e.g. the ways via which humans could construct machines) knowledge. The similarity in the organisation of university departments meant that the sets of behavioural patterns used by PhD students, research associates and staff in general were also remarkably similar. However, this similarity faded the moment an agent

left the university and moved on to examine the institutions that actually did construct marine energy devices, such as developer firms.

Beyond university education, in an innovative sector such as the field of marine energy technology, technological capital could be developed in an environment of good communication and exchange of ideas among many agents. In fact, education could be described as one more method of knowledge exchange, i.e. as knowledge derived from the development of technological innovations in the past. Knowledge exchange however, could take place between institutions which were involved in innovative projects at the same time, as can be seen in the next extract from the interview of the leading member of the consortium of investors and developers:

“And I think there is a lot of vicinity between projects as well in terms of modelling and some of the cross-cutting innovations. So, you know, people can't afford to work in individual silos and be focused just on their own work. They've got to look across other projects looking at things that do work, that don't work, lessons learned and get advice for all the elements in terms of the sort of strategic use, sending out requests for proposals looking at project funding, looking at the delivery phase, looking at sort of future exploitation.”

Here, knowledge exchange between people involved in innovative projects was described as a key ingredient of the development of technological capital. In addition, as can be seen in the following extract

from the interview of a leading member of a testing facility, institutions populated by agents who possessed good amounts of bureaucratic capital and knew how to cooperate were one of the most important prerequisites for knowledge exchange:

“So we need to make sure that our services are of a good standard and what is particularly important for marine energy is, because it's a new industry, we don't have all the answers yet and we don't know what the industry will need yet. So, it's really important that we don't let down companies we work with and understand what their needs are and see if there is a, if there are things that [name of testing facility] can do to make it easier for them to address their technological development.”

The respondent mentioned that her institution helped developer firms more effectively if their ‘services were of a good standard’ and if they ‘understood what their needs were’. These however are sets of behavioural patterns which belong to the bureaucratic cultural capital described in the previous section. Hence, bureaucratic capital can be a prerequisite for the development of technological capital. It is important to remember that the two types of cultural capital analysed in this chapter are both crucial for the development of marine energy technology.

However, studying, communicating and applying the experience of other sectors was not enough if an agent really wanted to translate the knowledge he or she possessed into technological capital. The main reason was that through these processes technologists learned what was

already known about the creation of technology, i.e. they completed a long series of personal innovations. Going from personal to societal innovations, however, required more than studying. The agents would have to be able to actually conduct technological research. And since technological research meant the capacity to find new ways to interact with the enabling effects and the constraints of the independent dimension, the only way to conduct this type of research was to interact with the independent dimension under controlled conditions so as to be sure that the correct conclusions could be reached. In short, the final way to accumulate technological capital in order to achieve societal innovation was *experimentation*.

Following Pinch (1993), I will maintain that experimentation in the domain of technology takes the form of testing and that it is a crucial element of the innovating process as it takes place almost everywhere in the field and not only in specific positions. For example, in the following quote, a leading member of a small developer firm described how important testing was to his innovating procedures and to the challenges he had to deal with:

“It’s amazing the number of times things come out when you test that you hadn’t actually seen. That’s why it’s just very important for us to test and make sure it’s robust. And once we do that we are fine. Well actually quite, the way it works, in the company in that kind of work we are

quite, quite brutal, quite fierce in terms of our, our solutions.”

He considered actual testing the most adequate way to reveal a large number of tiny details which would have remained unseen if his firm had relied purely on past knowledge. It was the most adequate way of developing new knowledge and new sets of behavioural patterns capable of contributing successfully to the construction of efficient marine energy devices. Furthermore, it is not-surprising that the repetition of an experiment led to the generation of more knowledge. Each time the experiment was repeated the technologists knew better what was happening and hence, were capable of observing more details.

I have to point out that experimentation was different in each position in the field. For example, university researchers, experimented with the help of simulation software, as I described in Chapter 7. Developer firms facilitated their experimentation through the function of institutions which aimed to provide the best possible conditions for experimentation. These institutions were the testing facilities, the purpose of which was to establish ideal conditions for the testing of marine energy devices after the latter had left the laboratory and had to experience functioning under realistic conditions. This was the reason why testing facilities were one of the most important institutions of the

core of the field of marine energy technology, as demonstrated by the following quote from one of their members:

“Lots of people have very good ideas that they can develop this technology using computerised design, using clever modelling or hydrodynamics but until they are actually sold as full size quality machines and get to work into real sea conditions, it's only a point of view and just that. And so we think, the companies that we work with have done a huge leap forward in terms of developing their technology after they've managed to test their first machine in the water... So, the real sea testing is particularly important to the commercial viability of the industry. And the industry is commercially viable if we can prove that the machines can be replicated on a commercial scale, utility scale of power production and before we get to that point we have to prove that one machine can work.”

Even though this interviewee accepted the importance of simulation software and computerised design for the development of technological capital, she pointed out that a technological innovation could be considered reliable only after it had been tested into the ocean.

Experimentation in the ocean and successful response to the challenges posed by it provided the developer firms and their products, i.e. the marine energy devices with something equivalent to Bourdieuan institutionalised cultural capital. It was a signal that specific types of sets of behavioural patterns related to the successful construction of marine energy devices had been obtained and that the developer could successfully deliver marine energy devices. What's more, the provision

of such signals was not important only to single developer firms but to the industry as a whole. The survivability of the industry as a whole depended on the development of technological capital capable of overcoming the challenges of the oceanic environment. Without such signals the investors could abandon the sector.

However, the complexity of the oceanic environment was not a problem only for the development of marine energy devices, but for their testing as well. Among the challenges of the oceanic environment was the cost of experimentation, as can be seen in the following quote from a leading member of a testing facility:

“In the marine energy sector, what tended to happen so far, is that those people that had an idea have tested their concepts at a very small scale let's say may be 1/100th scale. They've been, depending on which developer exactly you are looking at, some of them went straight to building something up saying 1/4 of full-scale, which is then deployed in the sea and it's usually gone wrong. Either not performed well or very difficult to deploy or they need longer to get them to work properly than they expected. All of which costs money and all of which takes time.”

No matter how important experimentation in the oceanic environment was, the high cost of testing in terms of both money and time hindered many developers from appropriately testing their devices.

Nevertheless, the need of the industry to prove that the necessary technological capital was in place continued to exist. An innovative testing facility was developed to solve this problem. One of its leading members described it in the following way:

“What [name of the testing facility] offers is an opportunity to test at may be something like a 1/10th or a 1/20th scale in simulated and controllable conditions within a lab and onshore. So, it's a way of de-risking designs as well as improving their performance before you incur the very high costs of making something big enough and strong enough to survive at sea. So, it's a good way to de-risk and get a design before you then start cutting expensive metal and using all sorts of metals to deploy that metal at sea.”

The interviewee claimed that the main function of this testing facility was to reduce the complexity of the testing of marine energy devices by testing them in a controlled environment and at a much lower cost. By standardising the process of testing, the developers had the opportunity to obtain cheaply some very useful knowledge which could prove to be critical for the successful completion of their tasks. Hence, this new testing facility aimed to develop technological capital at a much lower cost, before the testing of devices in the ocean. This institutional innovation would help significantly the development of the field, if it signalled to the investors that there was abundant technological capital.

The need to develop more technological capital was obvious to many interviewees who had diagnosed it as a problem of the field that appeared due to its newness. For example, a leading member of a consultancy firm complained about the absence of a code of standards from an engineering perspective:

“From an engineering perspective, the problem I think is having an appropriate code of standard of what people can design against or a process that can design a certification for us. One of the biggest problems is, in some respects we move with large areas or large manufacturers that are not used to dealing with certification authorities and we have to understand their requirements of what they're generally looking for. Also we've got the other extreme when you've got very small companies which are financing their device developments themselves and essentially you need to cover all of that room and anywhere in between.”

A code of standards could have been a perfect proof that the sector was no longer in its infancy. However, such signals did not exist and consultancy firms had to accept that they would have to adapt and reinvent their working procedures depending on the institution that they had as a client.

The relative absence of the necessary technological capital in the sector was the reason why a leading member of a testing facility argued that institutions in the core of the field had to advertise the technological capital they had gathered through their work to attract the attention of other institutions, as can be seen in the following quote:

“Another part of our job is using the work at [name of testing facility], using our research, using our website and other forms of communication to spread the message about [name of testing facility].”

Advertising aimed to convince its clients and investors that they would be able to partake in this capital if they cooperated with the testing facility.

However, technological capital was an essential resource not only to collaborate with other institutions but also in terms of competition within an institution. Leading members of an institution needed to prove that they possessed a certain amount of technological capital, as a leading member of a public institution put it:

“You had to be prepared to constantly go out and create a reputation...There's a reputation that you need to have, authoritative to a point but there is no way you are going to deny that I had to work in areas where I had no authorities for example ornithology and marine mammal science and I did. The key was to find a way via which I could enter those fora and have contributions to make that people would recognise as being authoritative. And the way you could do that was by going in and talking about the application research. So, you need to be able to go in and talk to a wide array of fora in a way that steers those fora and raises the reputation of (name of institution) both nationally and internationally. So get a reputation which involves certainly a degree of authoritativeness when you have to do with people around and you have to speak with people in meetings. There's ways of doing things, there's ways of making your presence felt.”

The most interesting part of the quote above was that this interviewee seemed to suggest that, if agents had already convinced other agents of the field that they possessed sufficient amounts of technological capital in specific domains and had already emitted successfully the corresponding signal to the other agents of the field, then they could replicate the emission of this signal even in domains for which they did not possess the same amounts of technological capital. And even in that case, they could have the confidence that their employees and peers would respect them and their actions.

To conclude, I have to point out that technological capital was one of the most important determining factors of the hierarchy of institutions and agents in the field. Demonstrating that they could overcome specific technical challenges and contribute to the construction of marine energy devices was the most useful type of knowledge that agents could possess in the field, especially at its core. The types of institutions that were created to develop technological capital depended heavily on the characteristics of the independent dimension. In the case of the field of marine energy technology, the high cost of experimentation obliged the agents of the field to create two distinct testing facilities. Finally, like bureaucratic capital, technological capital differs from its Bourdieuan counterpart because it is reflexively developed and pursued by the agents of the field.

Finally, it is worth pointing out that the efforts of the agents did not always result in a successful outcome and neither did the technological field remain static, such that all plans came to fruition as planned. On the contrary, the protean form of the technological field guaranteed that its agents would have to compete and collide due to the different types of targets and types of cultural capital which corresponded to their niches. The final section of this chapter will be dedicated to the presentation of the various types of disharmony found in the field.

9.4 Rupture

Before I describe the cases of disharmony in the field, I have to stress that they did not always hinder productivity. Envisaging disharmony only as an obstacle to innovation would constitute a simplistic understanding. Disharmony should be understood as something that could both enable and constrain the agents of the field, as well as generate specific qualitative characteristics to the innovations which are realised therein. I will present the two main cases of disharmony in the field, i.e. the conflicts between distinct types of bureaucratic capital and between bureaucratic and technological capital.

9.4.1 Different Types of Bureaucratic Capital

The first case of disharmony in the technological field had to do with the confrontation among agents who bore qualitatively distinct types of bureaucratic capital. I described bureaucratic capital as a form of cultural capital which was generated when the agents accumulated knowledge about how to interact with other agents in the institutions of the field that they participated and then used that knowledge to advance their interests. Within this context, precisely because the technological field included a multiplicity of diverse niches, the bureaucratic capital each agent possessed was qualitatively distinct. Certainly the differences were not so large as to justify the treatment of the bureaucratic capital of each niche as an entirely different form of cultural capital. After all, universities, private firms and statutory institutions were all types of bureaucratic institutions. Nevertheless the differences were large enough to cause disharmony at times. Sometimes, the agents that tried to cooperate did not ‘talk the same language’ and could not deliver what they were supposed to.

An example of the tension between two types of bureaucratic capital was the divergence between the opinions of a member of a public institution responsible for the protection of the environment and the leading member of a small developer firm. The former worked in an

institution that had a regulatory role whereas the latter was leading an institution that determined the future of the field. The control of developer firms by public institutions, which were responsible for the protection of the environment, was a largely bureaucratic function.

When asked if she had anything important to add to the interview, the member of the public institution rushed to placate the private sector by stating that her institution did not wish to function as an obstacle:

“I guess what's really important for me, and I guess that is an individual perspective, is that I have already said it earlier on, we want to see sustainable development, and we don't want to block development. And I think sometimes [name of her institution] is perceived to be obstructive or just not enabling enough and I think that as far as I'm concerned, my goal always was to get that balance right, between fulfilling the need for the developer and the Scottish Government, because that's the key point to work where we can with the developers to find solutions. So, I think that's quite an important point from my point of view. Understand the need for sustainable development.”

On the other hand, the leading member of the developer firm had quite a negative view about the regulatory institutions that protected the environment as can be seen in the following quote:

“I think the biggest problem is red tape. Regulatory red tape. I think, you know, we had, problems with [name of public institution], the environmental agency. It was not fault of our own. Simply because of the nature of their organisation they've almost put us out of business, even

though we were always following the guidelines that they gave us. And it's a cultural problem in the [name of public institution]. They're probably the biggest threat to our business unfortunately.”

The employee of the public institution tried to appease the private sector and to justify the existence and performance of this institution as something necessary. On the contrary, the member of the developer firm was not afraid to accuse the public institution as being one of the main obstacles in the development of the sector. He did not believe that a high level of inspection should be considered a given in a sector that aimed to improve the sustainability of the Scottish economy and not to just fill its seas with environmentally flawed devices. The difference in their expectations about the interaction between public and private institutions was due to their distinct positions in the field. The difference in the expectations and the use of sets of behavioural patterns, which might lead to conflict, are an example of disharmony between the technological capital developed in distinct positions in the field.

9.4.2 Bureaucratic vs. Technological capital

The second case of disharmony in the field was the one between bureaucratic capital and technological capital. This type of disharmony was acknowledged mostly by the agents of the field who were active in

research intensive positions. A university research associate suggested that researchers and technologists had to abide by the needs of the industry, which in the case of the field of marine energy technology, was of course the private firms:

“I think that the greatest problem for some researchers to overcome in order to succeed is, first of all, relevance for what the industry is doing and second of all its engagement with that industry... If you can prove that you're sort of relevant to industry, then you can engage with them. The industry don't have an appetite for engaging with academics who are doing abstract things in a back room somewhere that is not relevant to them and I think that's no use in terms of our research being successful... Keep your things relevant, engage within the industry and at the end of the day it's the industry that is sort of taking the sector on, not just research. So, that interface between the industry and research I think it's sort of critical, critical challenge for us.”

The research associate argued that the success of the agents of the field who engaged in technological research depended on their capability to understand the views and needs of the private sector. To achieve their target they had to convince the private sector and thus make their research appealing to the private institutions which had the capacity to provide the necessary funds. Hence, they had to utilise the bureaucratic capital that allowed for a satisfying cooperation with the private sector as much as their technological capital.

This principle applied not only to low ranking researchers of universities. It also applied to entire institutions of the core of the field, such as some public regulatory institutions, as a leading member of this institution described:

“It's the very applied science that we have to specify, because the whole drive has to be towards getting devices in the water, getting projects in the water. There is, there is not a lot of drive to do the more theoretical research the more environmental research that is not directly applicable. For example, there's not a lot of pressure to work on the impact of turbulence in tidal turbines on sea plants and grazing works. We could do that...But at the moment no-one is asking that. They do not even raise that as an issue because it does not have direct relevance to licensing...Very, very reasonable scientific target. Absolutely defensible in some fields, but not defensible in this one, not justifiable in this one.”

The predominance of the tenets of a specific type of bureaucratic capital in a technological field induced the agents therein to pursue specific types of technological knowledge and hence, to accumulate technological capital with specific characteristics. Knowledge about the relation between tidal turbines and sea plants was neglected by the technologists who constructed marine energy devices, because they followed the dictates of the private sector. This case of disharmony did not impede the development of the sector but it significantly reduced the sustainability of marine energy devices.

9.5 Summary

This chapter aimed to describe the internal characteristics of the field, i.e. the various types of instituted cultural capital, which the agents accumulated therein, and which in the end were the determining factor of its form and function, along with the relations with the other social loci analysed in Chapter 8. I analysed the key characteristics of the technological field of marine energy as a late modern social phenomenon comprised of bureaucratic institutions in which the participants accumulated for bureaucratic and technological capital. I described the key characteristics of each form of capital and highlighted the importance of flexibility in the case of bureaucratic capital as well as the ways in which technological capital could be accumulated, i.e. through education, experience obtained in similar technological fields and experimentation. Finally, I described the key occurrences of rupture in the field, i.e. the conflict between different versions of bureaucratic capital and between bureaucratic and technological capital.

The existence of more types of capital than the financial is the reason why this research avoids the economism of Marxist analyses (Marx, 1867). Power relations within the field were determined not only by economic but also by cultural factors. Hence, the technological field is congruent with Weber's (1905) argument that the cultural and/or

economic determination of human action should be regarded as a conclusion of research and not as an axiom. In the case of the technological field, researching the field should lead to the discovery of the most important determinant factors of human action therein, i.e. the financial capital or the various types of cultural capital.

Nevertheless, the term cultural capital in this analysis does not imply that this capital developed without any influences from the material conditions in which the agents were active. On the contrary, the sets of behavioural patterns which comprised for example technological capital could not have been acquired by the agents had there not been specific technological artefacts. To be more precise, it was necessary to have specific equipment in order to learn how to become an electrical engineer. Now, when considering firstly that the financial capital was necessary for the construction and acquisition of this equipment, and secondly that cultural capital had effects on the production of technological innovations, then it is obvious that the two types of cultural capital encountered in the technological field could be described as market failures (Nicholson and Snyder, 2008). Specific economic actions (e.g. buying specific equipment) produced results that cannot always be calculated by the agents of the markets (the specific views of engineers regarding the qualitative characteristics of the machines they construct). The concept of the technological field is better able to investigate these

market failures because it avoids the reductionist approach of treating them simply as externalities as rational choice theory approaches do (Nicholson and Snyder, 2008).

Furthermore, the types of cultural capital and the differentiation in terms of power and influence in the field that they induced could be the solution to the problem of identifying the most influential social institutions for each technological entity. It was the problem that Russell (1986) identified as one of the key disadvantages of SCOT (Pinch and Bijker, 1986). By distancing itself from the economism which was resident in Marxist approaches such as Russell's (1986), the technological field allows for an easier and more complete identification of the most influential institutions and social groups.

Finally, the various types of capital that appeared in the technological field and the disharmony that was observed among them were perhaps one of the best indicators of the degree of autonomy and heteronomy of the field of marine energy technology (Bourdieu, 2001). If a specific type of cultural capital was more beneficial to the agents of the field, and in particular the agents who had more authority, then the majority of the agents of the field had firstly, to abide to its main tenets and secondly, to try to develop it in order to succeed in their targets. Hence, the institution that functioned according to this type of cultural capital was the one which dominated the technological field. The field of

marine energy was a relatively heteronomous field with respect to its relationship with private capitalist firms which provided the funding and hence possessed a lot of authority. This was not surprising for an early 21st century post-Thatcherist economy. The analysis of the technological field could however progress even more and, instead of simply stating that in general technological change was determined by the private sector, it is able to narrate exactly how this determination took place. In this chapter, I have just scraped the surface of this determination. The next chapter will be dedicated to the most accurate description of this phenomenon, as well as to the analysis of the extent to which the technological field of marine energy can be autonomous. In the following chapter, I conclude the answer to the institutional question.

Chapter 10: The Impact of the Technological Field

This chapter aims to discuss how the internal qualitative characteristics of the field of marine energy technology combine with its relations and links with other social loci, to determine the qualitative characteristics of the technological change of marine energy itself. This chapter completes the answer to the institutional question, i.e. it describes the technological field of marine energy and its institutions and explores the impact of the struggles therein to specific technical characteristics of technological entities. It demonstrates that it is possible to locate predictable patterns of similarity and divergence in the views of the agents of the field regarding qualitative characteristics of the technological artefacts which are produced by the field.

I will focus on the patterns which are related to the speed of development: whether or not the interviewees support the rapid scaling towards multi-megawatt marine energy devices or prefer a more modest step by step approach. The interviewee's views regarding this matter is one of the most critical parts of this thesis, because the speed of scaling *is* a qualitative characteristic of a technological process which agents in the field are capable of negotiating, i.e. it *forms part of the performed dimension*. Hence, asking about the speed of scaling was an attempt to ask about the future of technological development in the sector of marine

energy in a way that allowed for the identification of different approaches. The fact that the views of the interviewees revealed specific patterns justified the use of the method of the technological field in the study of the sector of marine energy technology. After all, the hypothesis of the existence of the technological field could be valid only as long as the position that the agents occupied within the technological field affected to a large extent the qualitative characteristics of innovations they produced therein.

I uncovered two patterns in the interviewees' responses about the potential speed of the scaling of marine energy devices. The first had to do with the distance of the interviewee from the early stages of an innovative project and revealed the impact of the distribution of technological capital in the field. I found that within the field of marine energy technology, the interviewees who worked in institutions active in the earlier stages of an innovative project, i.e. in institutions for which the bureaucratic and technological capital developed in the field were comparatively more important than their links with other social loci, supported the more modest approach to the scaling of the devices. On the other hand, the more involved the interviewees were in the later stages of the innovation process the more adamant supporters of the rapid approach to scaling they became.

The second pattern was about the amount of financial capital available to developer firms. Developers with comparatively more financial capital were in favour of rapid scaling which could potentially bring fast returns to their investments, whereas institutions with comparatively less financial capital regarded the modest approach as the most efficient. Finally, this chapter charted the field based on these two patterns and discussed the impact the field had on the technological sector of marine energy technology.

10.1 Context

Before the analysis of the two patterns, I will explain the term ‘speed of scaling’ and why it formed part of the performed dimension. The ultimate goal of the agents of the field of marine energy was to invent and produce a marine energy device capable of delivering power of many megawatts at a competitive and market-efficient cost. Before reaching this aim however, the agents of the field who worked in developer firms of the sector had to settle for less ambitious goals. Before managing to construct multi-megawatt devices they would have to succeed in building marine energy devices which could deliver significantly less power than multi-megawatts. The complexity of this process was immense since all marine energy devices (capable of

producing multi-megawatts of power or not) had to pass through various stages of prototype models which were smaller and capable of only delivering much smaller amounts of power. The speed of scaling was the speed of passing through all these stages until reaching the aim of the complete and commercially successful multi-megawatt device. This speed did not depend only on the characteristics of the independent dimension, but also on the willingness of the agents of the field to spend money, time and work efforts on the construction of larger and more efficient marine energy devices, wave or tidal. Hence, it was also part of the performed dimension.

Seven-teen interviewees commented on the speed of scaling. The remaining did not because commenting on this issue required knowledge of engineering and these interviewees were active in niches in the field which required different, unrelated to engineering, sets of skills². Half of the interviewees who did answer stated that the modest approach was the one they preferred. The reasons why they preferred it included firstly appeals to the independent dimension, such as for example when they referred to the complexity of the ocean environment which tended to cause problems to heavy machinery installed in it, or when they

² Those that did answer included three University members (a PhD student, a research associate, a research fellow), 2 politicians (a Conservative and a Green), two leading members of testing facilities, one employee of a consortium of research organisations, three leading members of developer firms, three members of the Scottish public sector, one member of a construction and repair firm, one member of a consultancy firm and one member of a developer of measurement instruments.

mentioned the environmental concerns that were related to the installation of the marine energy devices. Furthermore, they also mentioned reasons that could be attributed to the combined effects of the performed and independent dimensions alike. These included for example the technical hurdles that had to be overcome (and thus rendered non-feasible a successful fast scaling), the previously acquired bad experience from applying the fast approach to the wind energy technology sector, and the technical challenges related to the size of energy devices. Finally, it was not surprising that there were also some reasons that were derived entirely from the performed dimension of the sector of marine energy technology, such as the fear of failed large scale projects which could cause huge financial losses that might repel investors and the general lack of experience in the sector. All of these concerns are part of the technological and bureaucratic capital that the interviewees gained via their work in the field of marine energy technology.

Strikingly, only one interviewee, a leading member of a consortium of investors and developers, claimed that the fast approach was the correct option. His argumentation mostly focused on reasons that had to do with the performed dimension of the field, such as for example that marine energy should progress according to the ambitious development targets set by the Scottish Government in the Climate

Change Act (2009) as well as the need to compete at the price level with other types of renewable energy. Furthermore, he proved to be an adamant believer in the capability of his consortium to gather the necessary funding for the large and fast scaling.

On the other hand, a significant number of interviewees provided answers that could be described as ‘blurred’. Firstly, there were three interviewees who were unsure about the correct approach, and for different reasons: the leading member of a statutory institution responsible for the regulation of renewable energy which conducted scientific work, a university research associate and the leading member of a construction and developer firm. The former claimed that the development should be phased in order to test and find funding, that the ultimate outcome would be determined by the economy of the sector and, finally, that the independent dimension, i.e. the complexity of the ocean environment, would function as an obstacle which would reduce the speed of the scaling. The research associate on the other hand argued that the optimum size in terms of cost-efficiency was impossible to clarify due to technical hurdles and tried to gain some insight from the wind energy sector. As a consequence he believed that progress in the sector would be gradual but, due to lack of information regarding the maturation of the industry, it was impossible to predict. Finally, the latter respondent also referred to the importance of technical hurdles, such as

the factor that determined the speed of scaling, and added to this the even more decisive factor of cost-effectiveness.

Two interviewees (the member of a local authority and the member of the Green Party) comprised another category of unsure interviewees, however, it was obvious from their answers that they slightly favoured the modest approach, as can be seen in the following extract from the interview of the member of Orkney council:

“It's difficult. The devices are currently being tested. And there's a range of approaches. But it seems to me that there seems to be a need for robustness so, not necessarily the most efficient conversion of energy but who can survive the harsh conditions of the environment. So, I suspect it might be the second option [i.e. the modest approach] obviously with some respect for the technology to be efficient.”

As reasons for this preference they pointed to the complexity of the environment of the ocean and the experience of the development of the wind energy sector.

The remaining category of blurred answers were provided by three interviewees (member of a construction and repair firm, member of a research institution consortium and the leading member of a testing facility) who proposed that the industry should follow a combination of the two approaches. To be more precise, the member of the construction and repair firm was in favour of adopting a fast approach for tidal and

the modest approach for wave. The reason was that the risk for investors was analogous to the newness of a technological sector. A higher risk meant that one should have followed the modest approach. In terms of marine energy technology, tidal was a type of technology that was more advanced than wave and hence allowed for a less cautious development of the sector. The only constraint to the fast approach in the case of tidal energy had to do with the independent dimension: it was the limited amount of sites for development in the Scottish waters.

The member of the research institution consortium used different criteria to decide which of the two approaches ought to have been used. He argued that rapid scaling should have been reserved for those devices that would feed into the national grid whereas the modest approach was more suitable for community serving devices. The reason for the application of the fast approach in the former case was the determination of the government to develop marine energy technology. Distinct criteria were used by the leading member of the testing facility as well: the prototype stage should have developed at a modest pace whereas there was no problem if the rapid scaling were applied to those devices which had been proven to be reliable and profitable. Such a distinct treatment was justified by pointing out two factors: the complexity of the ocean environment and the shortage of funding for non-proven technologies.

Since ten out of 17 respondents either clearly or slightly preferred a modest approach, three were unsure and three preferred a combination of the modest and the fast approaches, it would seem that there had been a partial consensus among the various types of ‘experts’ who worked in the sector that some kind of a modest approach should be followed. However, this would be the conclusion of a research that does not follow the theoretical perspective of the technological field. If account is taken of the fact that the responses of the interviewees should at least partially depend on their location within the field, then the image that can be seen is rather different. In that image, two patterns can be observed which will be analysed in the next sections of this chapter.

10.2 Analysis: The First Pattern: Early Starters vs. Late Bloomers

The first important point is that the closer the interviewees worked to the early stages of the innovation process, the more favourable they were to the modest approach. This applied to the university students and staff, who were by definition the first step of a large amount of innovations. In fact, the members of university staff insisted that the fast approach had proven to be ineffective for wind power in the UK and US whereas, the modest approach was successful in Germany and Denmark. Among them, the research fellow proved to be a much more enthusiastic

supporter of the modest approach since he did not simply claim that it was preferable, but also went as far as to say that there were no supporters of the fast approach:

“I'm not sure who is advocating marine energy ventures to rapidly scale towards multi-megawatt devices. I think that's a longer term objective for the sector.”

This research fellow had been, during the past years, a member of a consortium of research institutions and he had not only been studying the sector of marine energy. Hence, he had known the sector in more detail in the earlier stages of its development.

In contrast, the research associate was actively studying the marine energy sector, and, to be more specific, the sector's commercialisation and development, its strategic direction and relative facilitating policies. Perhaps this more active involvement of the research associate was why he was not as sure about the modest approach as his colleague. As someone who studied road-mapping for marine energy, he had a much better knowledge of the technological capital gained by developers in recent years as well as of the maturation of the industry. Therefore, he knew much better the condition of the institutions which he confronted in the field. Hence, he was capable of recognising that:

“There's a lot of pressure on marine energy developers to upscale very quickly and to go from sort of scaled devices in the lab to bigger and bigger devices and to sort of emulate what's happened in wind. We've seen wind turbines go in the last 30 years from kilowatt devices to the now large devices, ten megawatts. There is pressure to upscale quickly and it's difficult to say if that's the best idea.”

Ultimately, his argument was that there should be an optimum size of device but that this size was very difficult to define. It would be the one that would offer a reliable and cost-effective energy production.

The same pattern seemed to be true for the personnel of testing facilities. It was interesting that the leading member of the testing facility which was responsible for the testing of marine energy devices at the earlier stages of their construction, i.e. *onshore* when they were only 1/20th to 1/10th of their final size, was fully in favour of the modest approach. On the contrary, the leading member of the testing facility responsible for the *offshore* testing of full-sized devices claimed that the modest approach was suitable only for the prototype stage of the development of marine energy machines. It was interesting to see how the leading member of the onshore testing facility described himself as someone who worked in an institution involved in the earlier stages of the innovation process:

“I suppose one of the things about [name of onshore testing facility] is what I mentioned about the de-risking.

[Name of onshore testing facility] always wanted to be the path to commercialisation for developers. And the analogy I usually make is like the Forth Road Bridge. So, on the Edinburgh side is all the great inventors with the lovely ideas and so on. And on the Fife side are fully commercial scaled projects, worth millions. In order to cross that gap, you need a bridge and that bridge needs supports. And [name of onshore testing facility] is the first of those two supports that we have on the Forth Road Bridge. And [name of offshore testing facility] is the second. So, [name of onshore testing facility] gets you from a clouded shape or bath hot tub design to something you can deploy at [name of offshore testing facility]. And then [name of offshore testing facility] gets you up to a commercial array and realizing your idea.”

This quote verified that the closer an agent worked to the earlier stages of an innovation, the more he or she supported the modest approach. The greater the distance was from the completion of a marine energy device, the greater the support to the cautious approach. This pattern was further followed by the members of the consultancy firm, the firm that develops measurement tools and the construction and repair company. Both the representative of the consultancy firm, whose work was to deliver know-how, and the member of the developer of measurement instruments, whose services were needed at the early stages of the process of innovation, were clear supporters of the modest approach.

The member of the construction and repair company, while proposing a combination of the approaches, still followed this pattern, as can be seen in the following extract from his interview:

“In terms of wave I think a more cautious, modest approach is needed. In terms of tidal I think the technology is relatively well proven now and it's about finding the right sites and making sure they are developed quickly.”

In this quote he argued that the modest approach should be applied in the subfield of wave energy, in which the devices were still not as commercially successful as in the subfield of tidal energy. And of course in the more advanced, tidal energy technology he claimed that the fast approach was far more feasible, if the constraint of the limited number of sites could be overcome. The achievement of closure (Pinch and Bijker, 1984) offers the opportunity to produce innovative versions of a specific technological artefact more quickly. In the case of marine energy, tidal was closer to closure than wave energy.

Similarly to the research fellow, the member of the construction and repair company argued that the modest or fast approach to scaling depended on the amount of technological capital gained by developers. The interesting thing however is that he did not only follow this pattern but that he was also sufficiently aware of it and could describe it in his own words and offer a rule of thumb:

“I think there has been a rapid scaling in the wind, offshore wind, so I think in each technology there's a different approach. But, and that's basically down to the technology. The less risky it is, the more rapid the approach is going to be.”

That rule of thumb however is remarkably similar to the answer offered by the leading member of a statutory institution, which conducts scientific work, who also argued in favour of applying the modest approach to innovations, which had not yet been proven as commercially viable:

“I think the industry itself would find difficulty in getting access to the huge amounts of money required for the very large developments without having some kind of a track record. Therefore I think the question will answer itself in that I think most developments will be phased.”

This quote revealed how a leading member of a research institution within the public sector argued that testing and proving that the technology was both reliable and cost-effective, i.e. developing technological capital, was the key to finding investors. Of course, there is the objection that this remark was not really valuable in terms of the topic of this analysis due to the fact that in his position he did not directly handle technological innovations related to marine energy, a fact of which he seemed to be aware of.

When he answered a question about the ways in which the function of his organisation affected the development of marine energy technology, his immediate response was the following:

“Technology marginally. And indirectly largely. Through the licensing process we facilitate the development of the [name of testing facility].”

Right after this response however he started citing all the ways in which the function of his institution had affected developers of marine energy technology and hence, the marine energy devices themselves. For example:

“So, on a more strategic level the first document that I produced has essentially steered the way in which the supporting scientific work has been done for the last few years.”

The list was so long, that immediately another question came into my mind: ‘why then did you decide to start your answer by saying that you affected marine energy technology marginally?’ And his answer was:

“Because I was thinking more about the engineering side. Like, we don't get involved in designing power trains for wind turbines or hydraulic systems for wave and tidal machines. That side of it, no. We don't, because it's not our expertise. We're not engineers of that type.”

Two things were obvious from this stream of responses. Firstly, this interviewee was not actively involved in the engineering side of developing marine energy technology. There was some distance between his work and the technological artefacts and perhaps this was the reason

why he was unsure about the correct approach. To describe it using the terms of my approach, there was some distance between the technological capital developed in the engineering subfield of the technological field and the cultural capital developed in his position within it. However, he did understand that he was involved in a technological field, in the sense that he influenced and interacted with developer firms enough (albeit indirectly) to have the capability to understand and cite the rule of thumb that the construction and repair company member previously cited.

This distance from the engineering side of things was not true for another member of a public regulatory institution. Hence, he was capable of having a more definitive opinion. And he was a keen follower of the modest approach. In fact, he claimed that the fast approach was not feasible. Again it is really interesting that his answer followed the pattern of having the people that were involved in the earliest stages of the innovation being more supportive to the modest approach. The same thing was true for the member of local authorities. His position was closer to the actual commercialisation of some devices that were clearly beyond the prototype stage. Hence, even though he was indeed unsure, he was only slightly favourable towards the modest approach.

Finally, this pattern was followed by the answer of the member of the consortium of research institutions that tried to promote the

commercialisation of university based research. He definitely occupied a position in the field that dealt with later stages of the innovating process than university students or staff, and acted as a facilitator bringing together academic expertise and developer companies. He did not believe in the sole use of the modest approach and instead proposed a combination: modest approach for the devices that would serve only the communities and fast and large scaling for those which would feed into the national grid. Furthermore, he added that the existing guaranteed funding derived from the government could serve as the necessary initial push that could accomplish the target of the scaling, even though he recognised that when the interview took place it was not enough for the development of the sector:

“I think both. I think actually a tandem approach. And that typically will work. I think we need to know how many devices are going to work in arrays... So, I would say people will be happy with their tidal array and they will deploy it, hopefully. I mean, 80 million quid, will go some in the way but you know, not even half of the way. So, it's going to oil the wheels but it's not going to go all the way... But the modest approach is important too. So that would be the community smaller generators that I'm talking about. There are lots of other companies looking at these small devices that will never be grid connected but, you know, isolated communities can benefit from that sort of thing. So, I'm thinking a joint approach. I think it would be folly to just go and stick a lot of steel into the water and hope for the best, because I think that's a very good way of throwing a lot of money away. We need to know that the devices can work together. Yes, a joint approach is the answer to this question.”

This analysis suggests that there is a relation between the tendency of the interviewees to value and prefer the fast approach and the closeness of their job position to the 'handling' of the later stages of the commercialisation of marine energy devices. However, even if this is so, it is worth asking why. Before answering this question, however, I will present first the second pattern that emerged from the answers of the interviewees, since the explanations for the existence of both patterns are related.

10.3 Analysis: The Second Pattern: Rich vs. Poor

So far this analysis has not included members of developer institutions, because their answers did not follow the first pattern. The reason for this is that developers are involved in all the stages of technology production and commercialisation. This is exactly what they do. They are not going to intervene at a specific stage such as the initial development of the idea (e.g. PhD students), the linking of researchers and firms, the onshore testing of a miniature, the later offshore testing of a device or the administration of all these stages. Instead, they are going to take an idea and go all the way up to turning it into a product that hopefully would be profitable. Hence, it would be difficult for them to

have a view of the field that would be related to any one of these stages alone.

However, even if it was by definition difficult to follow the pattern analysed in the previous section, another interesting pattern emerged in the responses from the three developers. Developer A was a construction start-up company that had only recently started to develop plans of innovating in the sector of marine energy. In fact the development of its potential innovation was still in the planning process. Developer B was a full-time developer of marine energy devices and at the time of the interview was very close in installing their first tidal device in the water. Nevertheless, they were also a small start-up firm whose device was relatively small and community owned. Developer C was a huge consortium of investors and developers of the private and the public sector which included firms such as the likes of Siemens and had the potential to support very large and expensive projects. What I discovered after the analysis of their answers and the analysis of the comments made by many other interviewees, is that the greater the size of a company and the easier access to private sector funding it had, the greater its sympathy for the fast approach. This was the second pattern revealed by the data.

Therefore, just as the theoretical approach of the technological field suggested, the answers of dissimilar institutions differed. Developer

A's leading member had not decided yet which of the two approaches, the modest or the fast, would be most appropriate for the successful development of the sector. Perhaps this uncertainty had to do with the fact that he had only recently joined the marine energy sector and that his innovation had been at a very early stage. It could be possible that he had not yet gathered enough technological capital in the sector to shape an opinion. Regardless of his unclear views about the speed of scaling, in the following quote he was able to give me some rules of thumb for the devices that would in the end prevail in the sector:

“I think the solution is not there yet. I think you can see a solution arrive when there's convergence of technology and...You look at the airplanes now and one airplane Airbus looks very much like a Boeing, you know. If you look at the wind industry, you know, a Siemens turbine seems looks almost always the same. If you stood back 1000 m. from a Siemens turbine, you wouldn't know if it were Siemens or Vestas or whose it was, because they all look the same. And OK, there are a lot of differences in detail but there's convergence... So, there's convergence because the technology has got to the point where it's all, it has got as efficient, you know, it's the most efficient it can be. And we don't see that in the marine yet. So, when there's convergence and that's all about pounds, pounds per watt. Pounds, I mean when the cost gets down to less than a pound per watt, then you will have found the solution.”

This quote revealed that it was possible to understand if a specific technological subfield had escaped its infancy by just examining its machines and seeing if they were all similar. The specific features of a

device or any other technological artefact stabilised as soon as this specific model of this technology had become cost-effective. It was really interesting to see an interviewee articulating a definition of what really is an effective technological solution, by stating something very similar to the definition of *closure* as specified by Pinch and Bijker (1984, p.426):

“Closure in technology involves the stabilization of an artefact and the 'disappearance' of problems.”

This answer provided material that could enrich the definition of closure and could make it more specific in case one of the relevant social groups that negotiated the form and function of a technological artefact was the *market*.

To talk in Pinch and Bijker's terms, cost-effectiveness is the criterion an artefact has to satisfy to solve the problems the people of the market have with it. However, at the same time the insistence of the interviewee in the importance of cost-effectiveness and his firm position that the solution would be found once the cost would become lower than a specific amount of money per watt, could perhaps be a hint towards the fact that particular social groups influenced more all aspects of the form and function of an artefact. Beyond the approach of the technological field, the latter argument was also supported by other approaches such as

Russell's (1986) Marxist critique of SCOT, which claimed that the social groups which influenced technological artefacts the most were determined by class struggle.

Developer B was very different from the one just analysed. Innovation in the sector of marine energy was not a secondary activity: it was their *raison d'être*, their true and only object of work. Furthermore, Developer B was the strongest supporter of the modest approach, arguing that this made its business model and tidal energy device unique and desirable. This was evident in the interview with one of their leading members who believed that the abandonment of the modest approach was exactly that, which led to the failure of many projects in the wind sector in the past in the UK and USA. This was the reason why these markets of the wind sector repelled the investors whereas the Danish and German market succeeded:

“Part of the reason why the UK and US onshore wind industries failed in the ‘80s and early ‘90s was that their technology development plan if you like was driven by overaggressive accountants and investors who quite rightly would want to get to the economies of scale of the large megawatt devices and instead of looking at what the technology could allow, they looked at what their balance sheets would show and they were driven by that, rather than with what the technology could do. And they went too big too quickly and because they had failures and they cost millions of pounds these failures, when they were growing at that scale... Economies of scale work for profits but they also work for losses. Because you had those big losses, the investors took fright and

left and over basically a space of almost some months, the UK and the US industries just collapsed. Whereas the Danes had taken a more gradual approach taking up small steps, they had the exact same problems in terms of the technology, but they could recover because it was at smaller scale. Therefore the investors didn't lose confidence, they kept with it and saw it through till the end, but it took a lot longer. You know, it really was the late '90s and early 2000s before the whole industry came to fruition."

Furthermore, the respondent provided an explanation of why the UK and US wind sectors followed the fast approach in the wind energy sector and why there was the danger of making the same mistake in the marine energy sector nowadays. It had to do with the—analysed in Chapter 8—'quick book' mentality of investors who expected to take their money back in less time than the one necessary for the correct and safe scaling of the device. The bureaucratic capital of the private sector's investors and the technological capital of specific developers in the field of marine energy had different priorities and promoted distinct types of innovating activity. Depending on the characteristics of the independent dimension of the field of marine energy, this conflict of interests could prove to be fatal for the development of the sector (as has already happened in the UK and US wind energy field).

However, Developer B did not simply reaffirm the conclusion of Chapter 8, as can be seen in this quote:

“It’s quite simple, the people and the companies that are venture capitalists, are investing, and want a turnaround within three to five years. And we will have megawatt devices, that’s where we intend to go because the economies of scale are there. We just think it’s going to take a little longer. But, it’s very hard to convince investors of that because that may take five to ten years to do it. Investors want to see that in something between three to five years... One of the biggest threats to our industry is the overselling of it. You know, people are saying that yeah we’re going to have multi-megawatt tidal farms and wave farms in, in the next three to five years and they all make very good progress but it’s not going to be at the level that people are promising and selling at the moment. And the reason they’re doing that is that they’re trying to get the investment.”

The interviewee not only argued that the fast approach was unsuitable for the sector of marine energy, but also claimed that there were other agents of the field who ‘oversold’ it, i.e. advertised their capabilities to use the fast approach. The reason why they did that was their need to attract investors to the sector. He did not simply declare that they created false expectations but also stated that these false promises were a threat to the development of the field.

A leading member of a public institution, which conducted scientific research, made a similar point. He argued that political overenthusiasm was the main cause of many failed projects in the field of wind energy technology, because it led to many ill-planned and not well-considered decisions, as can be seen in the following quote:

“There is so much political drive in this area at the moment, so much political support for the renewable industry in Scotland that it would actually be quite an interesting topic to see whether that's distorting the approach. Can we give some examples? There are some examples actually in the renewables industry. Back in the very early days of wind power there were some sites consented in Round one, Round two down in England that you look at them now and think why, you know? They look crazy. There are some devices that sometimes appear out of the water at low tide... Is our approach to consenting being distorted by economic and political enthusiasm such that we are taking unacceptable risk and making bad decisions? I don't know how to recognise that. That's enough to keep you awake at night actually. Because the sums of money involved are astronomic”

Hence, it is possible to assume that the view of overselling of marine energy technology—and in general overenthusiasm in the sector which could lead to wrong decisions—is not restricted to agents such as Developer B. Agents of public institutions, who did not face the need to present some results quickly in order to survive in the field, also rejected the fast approach. It is important to bear in mind the power of political and economic enthusiasm when taking into account that, as I analysed in the previous chapters, one of the biggest problems in the sector of marine energy is the shortage of investment.

The views of Developer B's leading member could not be further from the opinion of the representative of a consortium of investors and developers, Developer C. He was an adamant supporter of the fast approach due to concerns mainly related to the market of energy,

especially the need of the marine energy to compete for investments with other types of renewable energy, as can be seen in the following quote:

“Because of the way that the industry is moving, there's a sort of agreement that our next marine energy can make itself payable in terms of the level of the cost of energy by about, 2050/2060. Then, it'll be cost effective because of the technology currently undertaken... It's got to be able to compete on a par certainly with offshore wind and price to price compete with that. So, a cautious approach isn't going to get you there. And that's why [name of consortium] investment is important because we like to work at a local based case so that people can say that there is an investment opportunity or, you know, we tried and we really proved that it's not possible. So, I don't think the cautious approach is a viable one, I think that it needs sometimes to be bold and actually make those investment decisions.”

This support towards the fast approach was a justification of the opinion of the leading member of Developer B regarding the views of investors and I have to clarify if it was simply a coincidence, or if it revealed something about the field. It is important to take into account that the study of technological innovation is not like the study of demographics, where only aggregate measures are important. In the history of the development of technological artefacts, the acts of one person or one developer firm can affect the field as a whole and guide it in a different direction. Similarly, the views of a very small number of investors, developers and policy makers could prove fatal for the development of a renewable energy sector. In the field of marine energy technology, the

combination of shortage of investment and the adherence to the fast approach among a number of people who work in institutions capable to provide the necessary funds could be potentially decisive for the ultimate adoption of the fast and large scaling strategy. Hence, it is not the number of interviewees who adhere to the fast approach that matters, but instead, it is the type of interviewees who share this opinion.

And of course, the orientation of private funding and public support towards investments which intend to move rapidly into multi-megawatt devices means that funding and support for relatively small, community owned devices such as the one that Developer B is building, will be scarce. This scarcity forced the staff of Developer B to, not only adopt the modest approach, but to be so adamant about its importance as well. They have to differentiate their product not only in terms of its technical characteristics but also in terms of its business approach, so that it can be attractive to specific investors such as small communities. They have to innovate in terms of how they interact with the independent dimension as well as to accomplish an innovation in the performed dimension.

Thus, it could be that the fast and the modest approaches were nothing more than two distinct business plans and that their ‘correctness’ depended more on the location within the technological field where they

were applied such as a member of a consortium of Universities seemed to suggest:

“I think both. I think actually a tandem approach. And that typically will work ... We need to de-risk before we do that sort of thing and that's why test facilities will help. So, I think test facilities especially, specifically for array deployment are very important. But the modest approach is important too. So, that would be the more, the community smaller generators that I'm talking about, the likes of [another developer]. There are lots of other companies looking at these small devices that will never be grid connected but, you know, isolated communities can benefit from that sort of thing. So, I'm thinking a joint approach. I think it would be folly to just go and stick a lot of steel into the water and hope for the best, because I think that's a very good way of throwing a lot of money away. We need to know that the devices can work together. Yes, a joint approach is the answer to this question.”

This specific interviewee worked in a position where he had to bring into contact the private sector with universities in order to find funding for the latter's projects. As a result he knew the points of view of many different private firms and research institutions. Knowing the concerns of small and large firms gave him the opportunity to recognise the need for more than one institutional innovation in the sector, i.e. the need to have more than one business plan in the field of marine energy technology.

To sum up, the data revealed that there was a tendency for developers who were rich in terms of funding, finances and cooperative relations with the public sector, to favour the fast approach to scaling. On

the other hand, those with few financial resources and funding preferred the modest approach and highlighted more the issue of the technical problems of the sector. Nevertheless, it is now time to complete the discussion of these findings.

10.4 Discussion

The most concrete conclusion that can be derived from these patterns is that the interviewee's views are based on the amount of the different types of capital they possess. Among those who did not work in developer firms, the interviewees who were closer to the later stages of commercialising a specific device had to face the reality of finding investors and convincing them that their money would be returned soon (not later than in the case of a financial investment), as well as handling innovations that had been already funded to reach a certain amount of electricity production. For example, testing facilities had to deliver on the targets set by the Scottish Government. Therefore, they could not have been indifferent to a potential increase in the speed of the scaling and in general the commercialisation process. That was why one of their members insisted that:

“I think it's a combination of the two, and a cautious approach at the prototype testing stage followed by a large scaling speed in the development.”

On the contrary, people involved in the earlier stages of the development of marine energy were still further away from the commercialisation and the imperative of satisfying in the short-run their investors with a complete product. In addition, they were more aware of the technical hurdles that marine energy technology had to overcome. To describe it using the terminology of the technological field, their views regarding the speed of scaling were based on their experiences inside the field of marine energy technology, which had provided them mostly with amounts of technological and/or bureaucratic capitals generated inside this field.

This was true also for the interviewees who worked in developer firms. Those among them who were active in firms with significantly less financial capital, i.e. Developers A and B, tended to base their views upon the technological capital that they already possessed or that they would wish to acquire. That was why for example Developer B could not have stressed more the importance of developing more technological capital before scaling the marine energy devices. At the same time, Developer C emphasised more the importance of factors that had to do with the impact of other institutions on the field, such as the need to be competitive.

If some interviewees based their views mostly on the amounts of technological and/or bureaucratic capitals, which they accumulated inside the technological field, this did not mean that the institutions in which they were active were necessarily more autonomous. Sometimes, institutions with less financial capital or influence upon the public sector were in desperate need of financial capital and public sector support. One example, as I pointed out in Chapter 6, was that of the PhD students who were not able to complete their studies without the proper amount of funding. That rendered them largely if not almost entirely dependent upon sources of external funding, such as the private sector or public agencies such as the EPSRC. The reason why these interviewees formed opinions based on their technological and/or bureaucratic capital was not the autonomy they gained by following this recipe, but rather the fact that these types of capital comprised their competitive advantage. For example, small developer firms, such as Developer B did not possess relatively large amounts of financial capital compared to large investor's consortia such as Developer C, but they did possess bureaucratic and technological capital. These institutions would never be able to out-compete large consortia of corporations, such as Developer C, had they followed the same philosophy of innovation and a similar business model. *Ceteris paribus*, the institution with the most available funding would be able to dominate the technological field of marine energy. The

only way to survive such competition was to try to carve an alternative path to success and develop differentiated innovations and business models. Hence, in the case of UK's marine energy technology, small developers focused on the technical limitations of the application of the fast approach and on the promotion of the modest approach since it was a developmental path that they were capable of following, based on the knowledge and working ethos they developed in the technological field.

As a result, by following these two patterns and the distribution of various forms of capital to the agents of the field, it may be possible to locate the institutions of the latter and their views about the speed of the development of marine energy in a way that could make possible a standardisation of the relation between their location and these views. Such standardisation however, can occur only if the study of the field can demonstrate that agents in the field interact differently with elements of the independent dimension, not only due to factors that have to do with their capability to create *ex-nihilo*, but due to the perspective of their radical creativity as well. The analysis in the previous chapters already established that the perspectives of technologists were shaped within the technological field. Hence, the differences in the qualitative characteristics of the technological artefacts or processes fabricated by agents in different locations within the field did not depend only on their idiosyncrasy but also on the internal organisation of the field; the power

relations therein and the way it interacted with the remaining performed and independent dimensions of socio-technical reality.

The second conclusion is that the differences in the interactions with the independent dimension have to be accompanied by specific institutional innovations in the performed dimension. These innovations take place according to a pattern that more or less corresponded with the pattern observed in the interaction of the agents with the independent dimension. Hence, two innovative technological artefacts or processes, which share more similarities with each other than with a third artefact, in the way their makers and users interact with the independent dimension, should be produced under more similar innovative institutional regimes. The institutions that produce them, from the organisation of their construction to the way they will be marketed should bear more resemblances, i.e. contain more similar types of capital, rather than with the production of an artefact that is more distinct.

Finally, the third conclusion of the analysis of these patterns is that the creators of distinct technological artefacts or processes, which have been produced in the same technological field to serve more or less the same purpose, are trying to out-compete each other. The agents of the field try to make sure that closure in the sector will take place via the establishment of their own technological and institutional innovations as the role model. This does not mean that there will always be one type of

technological artefact that will eventually dominate the markets and will lead to the extinction of every other type. Due to specific characteristics of either the performed or the independent dimension, there might be cases of fields where more than one type of technological artefacts eventually survive. What I mean however is that there is a *tendency* to eliminate the majority of possible types of an innovation until only one of them prevail, and closure is achieved.

In the previous sections of this chapter, I showed how these conditions appeared in the technological field of marine energy technology. The way the interviewees chose to interact with the independent dimension depended on their position in the field. Small developer firms favoured a slow and modest process of scaling, whereas large consortia preferred the fast approach. Agents who participated in institutions involved in the earlier stages of an innovative project favoured the modest approach, whereas those involved in the later stages did not reject the fast approach. The respondents declared that the fast approach was more suitable for tidal energy and not wind energy because closure had been achieved to a certain degree in this subfield. Hence, it was possible to trace the views of the agents in the field through the study of their position in the field. Furthermore, each of these two distinct technological processes, i.e. the fast and the modest approach to scaling was accompanied by distinct institutional innovations, which again

developed similarities and differences according to the same pattern. Hence, a small developer firm could potentially achieve success by focusing mostly on the cooperation with communities and the search for non-corporate funding whereas a large investors' consortium would rely on large corporations and governments for funding.

This analysis completes the answer to question four, i.e. the institutional question. As the theory suggested, the internal organisation of the technological field and its relations with other socio-technical loci affect, to a large extent, the views of the agents of the field about specific qualitative characteristics of technological artefacts or processes and, hence, affect the future of technological change in the field. In the case of marine energy technology, the existence of developers with relatively more financial capital and developers with relatively more bureaucratic and technological capital, combined with the dependence from the private sector have led to the development of a technological field where small developers prefer the modest approach to scaling. On the other hand, big developers preferred the fast approach to scaling and this has led to the creation of two different types of business plans for the development of marine energy devices. Some small developers tried to construct small community owned devices whereas some big developers have tried to proceed rapidly to the construction of privately owned multi-megawatt devices.

10.5 Summary

This chapter analysed the impact of the field on the speed of scaling of marine energy devices. Scaling, i.e. the process of developing marine energy devices capable of producing more and more gigawatts of power is a technological process and its speed is one of its qualitative characteristics. The approach of the technological field argues that the views and subsequent actions of the agents of the field regarding specific qualitative characteristics of technological artefacts and/or processes depend on the position the agents occupy within the technological field. Hence, there should be recognisable patterns of similarities and differences in the views of the agents regarding specific qualitative characteristics of innovations, such as the speed of scaling. In the case of marine energy technology and the scaling of its devices, the answers of the interviewees revealed two recognizable patterns. In the first one, the agents who were involved in the earlier stages of the innovating process, tended to favour a modest approach to scaling and to reject a fast approach. The opposite was true for the agents who were involved in the later stages of the innovating process. The second pattern revealed that the higher the access of a developer to private sources of sources of funding, the more likely they are to prefer a fast approach to scaling. On

the contrary, those with less available sources of private funding are keen supporters of a more modest approach to scaling and argue in favour of developing alternative business models.

The key conclusion of this chapter is that the way each agent of the field innovates depends, to a large extent, on the experience of working in a specific position inside a technological field. The qualitative characteristics of the innovations of the agents of the field depend on the way their perspective develops as they experience work in a position of the field. Hence, even though there is always an element of unpredictability in the concept of radical creativity, understanding the internal organisation of the field and the way it interacts with the performed and independent dimensions, can help researchers understand the perspective of the radical creativity of the agents of the field, and hence, allow them to describe the qualitative characteristics of the innovations that take place in the various niches of the field.

In the case of marine energy, these two patterns revealed the uneasy relation between the technological field and the private sector. Even though the latter influences, to a large extent, the developmental paths of marine energy in the field, this influence is not always regarded as beneficial by all the agents in the field. Those who possess less financial capital and more of the bureaucratic and technological types of capital developed in the field tend to doubt the efficacy of the private

sector's initiatives. They accuse the private sector of neglecting the technical difficulties of the development of marine energy technology and for promoting a culture of quick returns, which could lead to the decline of the sector and the flight of investors in case a significant number of devices might fail. What they propose is that in lieu of the culture of quick returns and the fast approach, the field should scale slowly and develop alternative business models of innovating. Hence, the conclusion is that the views regarding a qualitative characteristic of a technological process, such as the speed of scaling depend on the relative amount of types of capital available to the agents of each position in the field. Those who possess relatively more technological and bureaucratic capitals will tend to carve a competitive advantage by using them.

This analysis, hopefully, demonstrates that the approach of the technological field incorporates all the useful elements of the previously existing socio-theoretical understandings of technology and at the same time avoids their deficiencies. For example, the network of relations of cooperation and competition among agents in the field as well as their interactions with elements of nature can be described in detail as can be seen in the discussion about the importance of testing facilities. However, this can be done without reverting to ANT's (Latour, 1988) flat ontology. Furthermore, just like Marxism (Russell, 1986) but unlike SCOT (Pinch and Bijker, 1984), the approach of the technological field can develop an

understanding of which social groups and/or institutions affect significantly the characteristics of specific technological entities. As can be seen in the analysis of previous sections it is possible to identify the precise impact of all institutions in the field as long as the researcher knows the amounts and types of capital available to them. For example, agents with relatively more technological capital will push for the realisation of innovations, in which this type of capital offers a competitive advantage, and hence, promote the modest approach and alternative business models.

Equally, the existence of more than one types of capital and the unpredictability of the radical creativity render this approach capable of escaping the economism of Marxism and the tendency of the latter to attribute all explanations to the macroscopic level of the analysis. This is why the exigencies of the private sector are not the only force determining the field. Moreover, this analysis can uncover the impact of the independent dimension since it is one of the factors that determine how many types of devices ultimately survive in the field. The complexity of the oceanic environment hinders the technologists' efforts to develop a single model of marine energy device, which can be used in every type of oceanic environment. This can be done however without reverting to technological determinism because the qualitative characteristics of devices are determined by the radical creativities of the

agents in the field. The elements of the independent dimension have been internalised in their perspectives as constraints.

Hence, the analysis of the dynamics of technological development in the field of marine energy completes the answer to the institutional question. Even so, knowledge of the characteristics of the field of marine energy, and in general any technological field and of their impact on the qualitative characteristics of innovation, could be beneficial to policy makers who could use this information to develop more effective policy measures and advice. The concluding chapter of this thesis will be dedicated to the thorough analysis of this thesis' contribution, as a scientific innovation, to other social loci such as the sociological field and the technological field of marine energy. It will also address the policy question.

Chapter 11 Concluding Remarks and Policy Advice

The purpose of this final chapter is to re-articulate the key points of my thesis. I analyse the key theoretical arguments of this approach and I explain the reasons why it offers an improved understanding of technological innovation. I also discuss the conclusions derived from its application to the sector of marine energy technology and to the study of the radical creativity of its agents. Firstly, I present the radical creativity of the agents of the field, which consists of a perspective constructed with recreations of elements of socio-technical reality and their capability to create ex-nihilo. Then, I proceed to the presentation of the key points of my investigation of the technological field of marine energy. I will emphasise the impact of the organisation of the field of marine energy to the qualitative characteristics of a specific technological process, i.e. the speed of the scaling of marine energy devices.

However, my summary in this chapter is inextricably linked to the discussion concerning the contribution of this research. Firstly, there is a theoretical contribution. The approach of the technological field aims to make the decisive step towards a more complete understanding of technological innovation in modern societies, and to offer fragments of a theoretical approach that can provide insights about any type of

innovative action of humans in modernity and not only technological innovation. These fragments could serve as the starting point for a discussion of the validity of the distinction between ensidic and non-ensidic Being of socio-technical reality as presented by Castoriadis (1975).

Secondly, this research has provided empirical evidence about the structure and characteristics of technological fields in general and the field of marine energy technology in particular. I will describe why knowing and understanding the key characteristics of technological fields could prove to be useful to various diverse and distinct types of agents, such as the agents of the field, social scientists, policy makers and citizens in general. Hence, I will address research question five, i.e. the *policy question*, and, to be more precise, I will attempt to present which characteristics of the technological field of marine energy technology would be useful to policy makers, agents of the field, the general public etc.; such as, for example, the two alternate paths to technological innovation which I discovered in my data. My ultimate aim will be to show which policy advice could be derived from such information. My argument is that knowledge of the organisation of technological fields is a prerequisite for a successful democratisation of technological change.

11.1 Theory

11.1.1 Theoretical Critique

After analysing in Chapter 2 a number of theoretical approaches to technological innovation, I described in Chapter 3 a new theoretical understanding of this phenomenon, which would overcome their deficiencies and take into account their strengths. My argument was that the key deficiency of previous attempts to understand technological innovation was their inability to escape the modernist image of an ensemblist-identitary socio-technical reality (Castoriadis, 1975). Even if previous approaches to technology made many contributions to the understanding of this phenomenon, they did not acknowledge the fact that technological innovation is a change, some aspects of which cannot be traced to any pre-existing element.

After the discovery and collection of the building blocks of a new theory in Chapter 2, what remained was its construction. In Chapter 3, I argued that a concept that used many of these building blocks and should be part of a new approach was Bourdieu's (2001) concept of the *field*, defined as a social domain where diverse agents engaged in a regulated struggle for various forms of cultural capital. The problem was that in the Bourdieuan (1972) version, the agents behaved according to their

habitus, i.e. through the internalisation of external structures (Bourdieu, 1980). Innovation, however, is an action that occurs without having been internalised in the past. This is why when discussing a specific technological artefact such as the television, Bourdieu (1996) focused more on the description of the already existing impact of television as it allowed for the emergence of a journalistic field and less on how the artefact itself was invented and utilised.

To escape this conundrum, following Brubaker (1993), I decided to combine the 'break', i.e. the creation of a new reality, and the idea of the internalisation of external structures. To achieve that, I founded my approach on the ontology of Castoriadis (1975), who described socio-technical reality as the result of the interaction between three factors: the first natural layer, the social imaginary and the radical imagination, i.e. the constant activity of the psyche for ex-nihilo representation and creation (Castoriadis, 1975). It is through the location of ex-nihilo creation at the level of the human psyche that Castoriadis managed to develop an understanding of technological innovation as change. Even so, he attributed the qualitative features of an innovation always to the encounter between the radical imagination and social imaginary significations. Hence, he failed to explain the occurrence of some innovations that were more radical than others, as well as why these occurred when they occurred.

This research proposed that, to overcome the reductive aspects of Castoriadis' theorisation, it was necessary to remember that the only way to innovate meaningfully is to create innovative thoughts, which are then combined with recreations of elements of the pre-existing socio-technical reality. The sum of these recreations comprised what I have called in this research the *perspective* of a new concept, *radical creativity*. Radical creativity consisted of the human capability to create ex-nihilo and the perspective that has been created over the years through this capability's interaction with socio-technical reality. To interact with socio-technical reality, humans rely on combining their innovations with recreations of elements of pre-existing socio-technical reality, which can be found in their perspective. This way, the concept of radical creativity could replace the habitus. Following this rationale, I described each technological sector as a *technological field*, i.e. an instituted social space where radically creative agents competed for various instituted forms of capital. The qualitative characteristics of the technological innovations, which appeared in the field, were determined by its characteristics and by the way it shaped the perspective of the radical creativity of the agents who worked in its institutions. In this way, my research became capable of understanding all three elements of the concept of technological innovation.

Chapter 4 continued with the articulation of the epistemology and the methodology of my research. I argued that the qualitative characteristics of technological innovations depend on the perspective of the radical creativity of the agents, which develops as they gain experiences within the technological field. Therefore, the perspective is a personal creation that depends however on the characteristics of each person's existence within the field. Obviously, this called for an epistemology that was primarily subjectivist, with some objectivist elements, which appear due to the co-existence of the agents in the field and the importance of the independent dimension. A methodology, which was congruent with such an epistemology, was a methodology based on semi-structured interviews, preceded by a period of background documentary research, the target of which was to identify and locate a specific technological field, the most important institutions therein and potential interviewees.

11.1.2 Reimagining the Theory

This section will articulate the theoretical contributions of the approach of the technological field. The first theoretical contribution of the approach of the technological field is that it is a "flexible" theoretical instrument capable of describing the local idiosyncrasies of each case of technological innovation without making it necessary to develop a new

theory for each case. That way, it is possible to avoid the danger of incommensurable propositions and to discover the main threads that connect all kinds of technological innovations in modern societies. To give an example, even though my research is dedicated to the sector of marine energy technology, both the concepts it uses, such as the field and radical creativity, and the conclusions it derives, such as the characteristics of the technological and bureaucratic types of capital, can be applied to and provide insight for other technological sectors as well. After all, every technological innovation in modernity depends on the institutions which participate in the technological field, the relations of the latter with other social loci, such as the public and the financial sector, the competition for diverse types of capital in the field and, last but not least, the independent dimension. The specification of these factors for different fields, subfields and positions within a given field is an empirical problem.

Secondly, the approach of the technological field does not underestimate the importance of technological change to socio-technical evolution. This is evident right from the choice to found the technological field upon the ontology of a magmatic Being (i.e. the abandonment of modernity's ensemblist-identitary character) and on the hypothesis that humans are capable of ex-nihilo creation through their radical creativity. These two foundations of my approach signify that my

interpretation of technological development is one of perpetual change; change is not an exception that occurs sometimes and researchers have to attribute it to human agency (Holmwood, 1996). Even though it was not possible to predict the exact ideas that the agents of the field produced, it was however possible to predict some of their qualitative characteristics based on the experiences they gained in their positions in the field. The fact that a leading member of a small developer firm embraced the modest approach to scaling and, hence, built a medium-sized community funded tidal energy device was related to the shortage of funding in the field and the need to outcompete financially stronger opponents through developing an alternative business model. What that means is that change is ever-present in my approach and researchers have to investigate how stability as perceived by human agents emerges from a number of small and large changes. This is even more important for modern societies, which, especially in terms of their relation to technology, are founded upon a continuous state of technological evolution (Misa et al., 2003).

Thirdly, the approach of the technological field does not underestimate the significance of technological change because the technological field is located in the middle-range between the human agents and socio-technical reality as a whole. By middle-range here, I do not imply that it is a middle-range theory; I just mean that ontologically,

it is among the socio-technical loci that lie between the single human agent and socio-technical reality as a whole. And since both the behaviour of single human agents and the evolution of socio-technical reality as a whole depend to a significant degree to the technology with which they co-exist, then understanding the technological fields of a given socio-technical reality is a *sine qua non* of its complete understanding. It is one of the key socio-technical loci in the understanding of how modern socio-technical order emerges from assemblages of humans and non-human entities.

Fourthly, being a concept that permits social researchers to understand when the agents of the field perform personal or societal innovations and their specific qualitative characteristics, allows for an understanding of the contribution of intentional and non-intentional effects of human actions to the emergence of contemporary socio-technical order. Unlike Giddens (1984), I do not accept that it is mostly the unintentional impact of the actions of human agents that matters to the emergence of social order. The technological field renders the study of the non-intentional effects possible by understanding, on the one hand, which personal innovations the agents of the field perform to mimic previously existing sets of behavioural patterns and what that means for the perspective of their radical creativity. On the other hand, it allows for an investigation of the impact of specific societal innovations to the

perspectives of other agents who have been affected unexpectedly. To give an example of the first case, it is possible to trace the unintentional effects of an experience, such as living close to a harbour that an interviewee had during their childhood, to the way they innovate and the field where they chose to work. To give an example now of the second case, once an innovation has occurred (such as for example a medium-sized, community owned tidal energy device) then it is possible to examine the impact of experiencing a greater supply of energy on the inhabitants of this community. Similarly, using the technological field, makes it possible to study the importance of the intentional effects by examining which sets of behavioural patterns they are actually changing with their innovations and what that means, firstly, for the field itself and, secondly, for socio-technical reality as a whole.

Finally, the approach of the technological field could be a tentative step towards an enhanced articulation of the problem of the creative capabilities of humans. By creative capabilities I mean the human capacity to produce thought and, to be more precise, to produce original thought that has never existed before. While most theorists simply include this capacity to the problem of agency reductively, Castoriadis (1975) defined it as the capacity for ex-nihilo creation. This hypothesis, on the one hand, revolutionised the understanding of human society because it made change the most fundamental ontological

principle of human society; however, on the other hand, it did not manage to entirely reject reductionism because, due to the shortcomings of the concept of social imaginary significations and the inefficient theorisation of the way they relate to the radical imagination, it could not describe how and why the capacity for ex-nihilo creation is combined with elements of pre-existing socio-technical reality in order to produce thought that is distinct and innovative. In other words, there is an element of arbitrariness in Castoriadis' theorisation. I made a step towards the clarification of this issue by articulating the hypothesis that the capability to create ex-nihilo co-exists with the perspective that is created through the experiences that human agents have as they grow up; it is composed by recreations of elements of pre-existing socio-technical reality, among which those related to the field are of extreme importance. For example, learning the existence of opportunities in an innovative field significantly influences the decision of opportunists of other sectors to enter the field in search of a more successful career and, hence, bring their know-how with them. This knowledge would affect the qualitative characteristics of the innovations in the field.

Nevertheless, it could be possible to argue that I have not overcome Castoriadis' (1975) reductionism, since the ultimate root of all change is the human capability to create ex-nihilo. Indeed, it is true that, according to the approach of the technological field, ultimately all

change can be potentially unpredictable, even though its indeterminacy is much reduced due to the existence of the perspective. However, the need to uncover that socio-technical reality is a domain of absolute determinacy seems entirely unjustified to me. It is an exigency of modernity's ensemblist-identitary logic. A scientific innovation should not be judged by the amount of determinacy in its tenets, but rather by its capability to improve the understanding of specific phenomena. Hopefully, this thesis successfully argued that the ontology of a magmatic Being allows for a much enhanced understanding of technological innovation. Abandoning the premise of absolute determination from previously existing socio-technical reality allows for a real understanding of the relative determination from this reality. Furthermore, the idea of the internalisation of socio-technical reality through the recreation of some of its elements in the perspective and the way the latter is influenced by social loci such as the technological field renders sociology the science that is the most adept to understand innovation since it studies par excellence social loci.

11.2 Empirical Results

11.2.1 Radical Creativity

The first issue I analysed in my empirical chapters was the formation and function of the perspective of the radical creativity of the agents of the field. In Chapter 6, I presented data from the interviews that verified my hypothesis that it was possible to discover the traces of a perspective which human agents constructed over the years through their experiences in and out of the technological field and which they needed when creating ex-nihilo. The interviewees claimed that their decision to join the field of marine energy technology had to do with the experiences they had during their childhood and adolescence, personal interests and the values they possessed due to earlier experiences, such as the protection of the environment and the benefit of the local community.

Through the experiences obtained in the field, the agents conducted a large number of personal innovations and hence they learned how to behave within the field, i.e. they internalised a number of *sets of behavioural patterns*. Just as the approach of the technological field predicted, the more these patterns dealt with aspects of the independent dimension of the field, the greater their uniformity had been. Another interesting fact was that it was easier to adapt to a technological

field once one had already adapted to various other social loci in the past. Since the agents' creative capabilities varied and depended on the experiences the interviewees obtained as they grew up, then this was another indication that the human ability to create ex-nihilo did not function on its own. Instead, the contents of the perspective were critical for the innovating capabilities of human agents in the field.

After the analysis of the perspective, Chapter 7 was dedicated to the examination of the form and function of the second component of radical creativity, i.e. the capability to create ex-nihilo and the way it interacts with both the perspective and the rest of socio-technical reality. The first interesting conclusion that I managed to derive from the data was that the agents of the field conducted their personal or societal innovations according to the same pattern. This pattern consisted of finding a goal, reducing the complexity of the task at hand, deciding about a specific course of action among those examined and then doing the work as decided. The respondents used many ways to achieve the two first steps of the pattern, such as brainstorming for the former and backwards analysis and/or division of the problem into smaller tasks for the latter. One of the key ingredients of a successful innovation was the assemblage of as much information as possible before choosing a course of action. Hence, in accordance with the description of the agents' radical creativity which states that the internalisation and recreation of

pre-existing socio-technical reality is a prerequisite for innovative reflexive thought, I found out that the internalisation of the features of pre-existing socio-technical reality took place alongside reflexive thinking when the agents innovated.

11.2.2 The Field of Marine Energy Technology

After describing the radical creativity of the interviewees in the field, I proceeded in Chapter 8 to describe the technological field of marine energy technology and, more specifically, the description of the relations of the field with other social loci, such as the private sector, other technological fields and the general public. Despite a generous amount of public funding, the technological field depended on private sector funding for its survival and the views of the interviewees regarding this dependence differed according to a pattern. Interviewees who worked in institutions where funding was scarce, such as PhD students and small developer firms, were dissatisfied with these conditions whereas interviewees who worked in organisations capable of finding funding easily appreciated the oligopolistic structure of the market in the field. Beyond this frontier, the field of marine energy competed for personnel, resources and funding with other technological fields. At the same time, opportunistic agents who entered the field of

marine energy from other more similar technological fields transferred experience, know-how and tacit knowledge, even though know-how transfer from other fields could be hindered due to the competition for funding between the fields. Finally, the last frontier of the technological field, which I analysed, was the ambiguous relations of the field with parts of the Scottish public. The data from the interviews revealed that the interviewees considered that some parts of Scottish society were not convinced that investments in technological innovations were always beneficial. The modernist belief that technological development improves human living conditions is not always popular.

After the description of the frontiers of the field, the next step was to describe its internal characteristics. In Chapter 9, I presented the field as a modern institutionalised social locus mostly occupied by bureaucratic institutions. A successful career within the field of marine energy depended on whether or not each agent managed to internalise successfully two types of sets of behavioural patterns. Firstly, there was the bureaucratic capital which consisted of a number of sets of behavioural patterns designed to guarantee a successful handling of bureaucratic functions and relations within the field. The higher the position of agents in the institutions of the field, the greater the amount of bureaucratic capital they had accumulated. Secondly, there was another kind of cultural capital, which I named technological capital. The

technological capital consisted of all the sets of behavioural patterns that guaranteed the correct use of already existing technological artefacts and processes and the capability to invent and construct innovative ones. There were three ways to gain technological capital, i.e. education, acquisition of experience from other similar sectors and experimentation, or as the technologists of the field of marine energy used to call it, testing. Finally, there were many examples of rupture in the field, i.e. occasions where innovations were hindered due to the conflicts in the field; examples included the conflicts between agents who worked in institutions with significantly distinct types of bureaucratic capital, such as the case of conflict between private developer firms and regulatory public institutions, and the conflicts which emerged when the institutions involved possessed disproportionate amounts of bureaucratic and technological capital, such as the cases where the exigencies of the private sector obliged researchers to steer their research towards specific technological targets.

Chapter 10 used all the information developed in Chapters 5 to 9 to investigate the impact of the field of marine energy on the qualitative characteristics of the technological artefacts and processes produced by the institutions of the field. Two patterns emerged regarding a specific technological process, the speed of scaling, i.e. the speed of the transition from smaller scale devices to devices designed to provide multi-

megawatts of power. While everybody in the field hoped to achieve the production of such devices as soon as possible, some interviewees believed that this transition should be fast, whilst others favoured a more modest approach. The interviewees who were in favour of the former approach were firstly those who possessed the greatest amount of financial, bureaucratic and technological capital, such as large consortia of investors and developers, and secondly those who were involved in the later stages of the production of an innovative device. On the contrary, the more involved the interviewees were in the earlier stages of the production of devices, the more they supported the step by step approach. Similarly, the smaller the amount of various types of capital they possessed, the greater the emphasis on the modest approach. For example, the small developer that constructed their device via community-based funding is an aficionado of the modest approach.

Observing these patterns leads to several conclusions. Firstly, if research according to the approach of the technological field is conducted appropriately, then it is possible to chart the impact of the field on a specific qualitative characteristic of a technological artefact or process by paying attention to the amount and types of capital that the agents of the field possess—just as I did in the case of the speed of scaling. Secondly, to survive the competition in the field, alternative types of a technological innovation would have to be accompanied by

specific institutional innovations and alternative business models, as one can see in the differences between the approaches of large consortia and small developer firms. Thirdly, no matter how efficient the alternative institutional innovations, there is a limit to the final number of technological innovations which will survive the competition and will be used to perform a specific technological function and that limit is set by the characteristics of the independent dimension. However, competition in the field leads to a tendency to reduce the number of technological entities that perform each function, i.e. to achieve closure.

In the following discussion, I will try to highlight the contribution of this research in the theoretical and empirical investigation of the phenomenon of technological innovation. Moreover, I will try to describe any policy advice that could be derived from this analysis and to address any issues that remained insufficiently explored by my approach.

11.2.3 Addressing the Policy Question

I mentioned in the discussion of the theory of my approach that the technological field is one of those socio-technical loci that lie between the human agent and socio-technical reality as a whole and at the same time provide key insight for both. This is the first reason why the technological field offers social scientists the opportunity to

investigate technological innovation using a ‘lens’ as wide or as narrow as they desire. What that means is that social scientists are now capable of examining the interactions of a specific agent or institution of the field, of a specific subfield, of specific types of institutions within the field, of the technological field as a whole or of the impact of its interaction with the entire socio-technical reality. Of course, this is not a characteristic unique to my approach. The contemporary literature of marine energy has spotted the need to develop models and frameworks that combine approaches better equipped for case-specific understanding (e.g. the innovations systems approach) and approaches which attempt to develop overarching and generalising models of specific aspects of technological development, such as cost-reduction (e.g. learning rate models), as can be seen in the following example from Winskel et al. (2014, p.97):

“However, despite a shared concern for understanding the role of technological innovation in system change, there is strikingly little cross-over between the abstracted representations of technology learning in learning rates and system modelling, and the contextualised, contingent accounts of innovation studies.”

An important advantage of my approach is that it is possible to move from the general to the special case without accepting any reduction in analytical rigour due to incommensurable theoretical propositions.

The problem of incommensurable theoretical propositions has been overlooked by contemporary STS middle-range theorists, such as, for example, Geels (2010, p. 508) who combined more than one approaches in his Multi-Level Perspective (MLP) model without synthesising them. On the contrary, fitted with the theoretical tools of my approach, social scientists are capable of examining technological fields, which include institutions that are active in many countries or specific cases of community-led technological developments. In any case, the key for successful understanding will be to uncover how the organisation of the field affects the radical creativity of its agents and to be more specific, the way the agents enter the field, its frontiers with other socio-technical loci such as the financial or political sectors and the characteristics of bureaucratic and technological capital which they accumulated. The investigation of these factors is an empirical problem and can explain why successful innovations occur in the positions of the field where they occur, whereas other innovations in other positions of the field do not obtain the desired qualitative characteristics and fail. The technological field allows social scientists to attribute the success or failure of specific innovations to the complexity of the independent dimension, the presence or absence of specific innovative institutional designs and/or the absence of personnel with the necessary qualifications and experiences. Understanding all these factors, which hinder or enable

technological innovation, can help social scientists realise which paths towards the achievement of innovations with specific characteristics are being currently pursued and which others could possibly emerge in the future. To give one example, my research has shown that currently the agents of the field pursue two paths towards the scaling of marine energy devices: the rapid and the modest. Knowing these two paths are being pursued means that social scientists could identify how to enhance the construction of marine energy devices along these two paths.

No matter how different, the technological field does share with contemporary marine energy literature several conclusions, such as the fact that public support is a *sine qua non* of technological innovation and definitely something that has to be gained in contemporary late modern societies (Bergek and Jacobsson, 2003). The uneasy relationship with the private, financial sector is also something they share. Not unlike my interviewees (in particular developers and investors), Agterbosch et al. (2004) concluded that privatisation was one of the factors which hindered the development of renewable energy in the Netherlands whereas Winskel et al. (2006) noted that this is particularly important in the UK with its history of liberalisation of the energy sector. In fact, even though the international experiences of innovation in sectors of renewable energy revealed that the role of social capital (defined as the collaborative learning between various distributed agents) was critical,

the UK energy system has always considered financial capital more important for the development of renewable energy (Winskel et al., 2006, p.365).

Another conclusion of my research, which confirmed the uneasy relations between the field of marine energy technology and the private sector, is that investors in the marine energy sector were reluctant to invest because they considered the field too risky. Hence, attracting funding was difficult and when doing so, investors were looking for a reliable and stable policy environment and a satisfying track record of any new technology (Leete et al., 2013). As Leete et al. (2013) uncovered whilst researching the sector of marine energy technology in the UK, venture capitalists, a financially powerful category of investors, only invested if there was a very short return. This result mirrored the conclusion from my analysis that financially strong agents of the field would push for faster scaling of marine energy in order to get their money back sooner:

“The venture capital investors interviewed invested because they had seen the potential to create value in the businesses, and then exit, in less than two years.” (Leete et al., 2013, p. 873)

Investors' risk aversion was further obvious from the fact that, as Leete et al. (2013) revealed, those that did invest in the early stages of a marine

energy device did not want to repeat this action should an opportunity appear because they had realised the real perils of such an endeavour

Nevertheless, even though the approach to the technological field outlined here shares some conclusions with other STS approaches, this does not mean that the latter could function as its substitute. As I mentioned earlier in this chapter, the key advantage of the approach of the technological field is that it is both coherent, in the sense that it avoids the problem of incommensurable propositions, and integrating the capacity to study various aspects of technological change at many different levels. Furthermore, I explained in the theoretical part of this chapter that it provides clear instructions about how to conduct interdisciplinary research and how to integrate the knowledge generated by social and natural scientists and technologists. Therefore, if contemporary literature (Kerr et al., 2014) claimed that social scientists should actively engage in the investigation of the following aspects of technological development in the sector of marine energy—namely economic impacts, wealth distribution and community benefits, communication and knowledge flow, consultation processes, dealing with uncertainty, public attitudes and planning processes—then the technological field could provide the framework for the integration of all these distinct and diverse research projects with the work of the technologists and natural scientists in the field.

A second and even more important reason why the technological field is more than a simple substitute for these other approaches is exactly the fact that it emphasises the qualitative side of technological production and change. When making future projections about the value of projects as huge as the development of marine energy, researchers in the sector usually apply variants of input-output models that may differ only in assuming a relative scarcity of the amounts of labour and capital (see for example Allan et al., 2008). Based on such premises, researchers are able to quantify the impact of the development of marine energy technology on other industrial sectors and the economy as a whole. What this type of research misses however, is the qualitative characteristics of this change. To calculate the progress of a specific sector and the speed via which learning by doing and/or learning by research will reduce the cost of a technology, it is important to be able to estimate the types of agents that will eventually join the field. A field that receives opportunists will evolve in a different way than a field that receives only resentful employees who failed in other technological fields. A field, that 'steals' highly competent personnel from other fields will have a different impact on other sectors of the economy, from a field which is not so attractive. A field that is organised or that contains elements of the independent dimension, so that there can be more than one potential paths for technological development will evolve in a different way than a

field which is dominated by a specific paradigm of technological development or a field in which closure has already been achieved. The only way to understand all these effects however, is via the enquiry of the radical creativity of the agents in the field. In the case of the field of marine energy technology, it is important to describe and understand the advantages, disadvantages and impacts of both the two distinct paths to technological innovation, which I discovered, i.e. the modest approach to scaling and the fast approach.

Furthermore, analysing the core of the field means naturally investigating, to a large extent, the views and work of the scientists who are active therein either in university departments or in developer firms. The examination of the conditions of their work should provide some insight about, whether or not there are some factors that hinder their efforts and whether or not there should be some changes in the way they work. For example, my interviewees who worked in universities, all claimed that marketing their research took too much of their time. Of course, agents of the field who are active in different positions of the field will have different and sometimes contrasting views about these factors and in general their working conditions. Be that as it may, the thorough examination of the technological field and its development allows for the identification of elements of truth in each of these views and explains their differences. In addition, since the approach of the

technological field focuses on the qualitative differences in the radical creativity of the agents of the field, it manages to reveal something even more important: the consequences of these conflicting views. Hence, depending on the effects of the views of the agents in the field on technological innovations, researchers could provide policy makers with advice about how to increase or decrease the relative autonomy of specific positions within the field and even of the technological field as a whole, in order to achieve specific results.

Therefore, policy makers could apply the information it provides to steer the technological innovations in a sector towards a specific direction. Since Scotland's target is to install three GW of marine energy power (Allan et al., 2008) and given that they know the paths that technological development follows in the field, they could even take measures capable of interrupting some paths or enabling others to achieve the desired outcome. Institutional innovation in the sector could even lead to the technology following an entirely new path. The ability to influence the path of technological development is congruent with the analysis of contemporary science and technology studies which claims that technological trajectories are determined by both emergent and deliberate path creation (Meyer and Schubert, 2007), i.e. through the actions of specific agents of a technological sector.

Here, this thesis comes to an end. Its main purpose was to provide an improved understanding of technological innovation and especially of the relations between social loci and the qualitative characteristics of innovative technological artefacts. I managed to show that there is a thread that connects the experiences of the agents in a technological field with their views about the characteristic of a technological process such as the speed of scaling. Nevertheless, this research has only scratched the surface of the technological field of marine energy technology. The speed of scaling was only one of many qualitative characteristics of the process of developing marine energy devices. Uncovering the impact of the technological field on all these characteristics requires further research. Even so, the fact that this approach emphasises the analysis of the qualitative aspects of technological development allows for the development of a richer description of technological development in a sector. Since democracy is meaningful if it offers citizens the opportunity to choose the qualitative characteristics of their lives in the future, approaches such as the technological field are important tools for the democratic control of technological development.

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Appendix

Interview Guide:

What follows is the interview schedule I used in my thesis. The questions are categorised according to the directions found in Chapter 4, Section 4.3.2. I did not address all the questions listed below to all the interviewees, due to the different position each of them occupied within the technological field of Scottish Marine Energy. However, all the interviewees were asked at least one question from each of the categories listed below. Each of the questions is followed by the various probes, prompts and follow-up questions I used in order to clarify the answers of the interviewees.

Introductory Questions

1. *Could you please tell me some details about yourself, and, to be more precise, some details about your education and your current and past employment? What got you into this area of work?*

Probes, prompts and follow-up questions:

- Why were you interested in it?
- Why did you decide to study...?

- Why do you like the...?
- Was it a conscious decision to join the sector of... or did it just happen?

2. *Could you describe your current employment? What are your responsibilities?*

Probes, prompts and follow-up questions:

- When I mentioned responsibilities, could you, for example, describe one of your projects?
- Are your responsibilities similar in the other working position that you have right now?
- Do you think that there is conflict between your two roles? If yes, in what does this conflict consist?
- Could you elaborate a little bit on working with...? So, how do you provide this guidance?
- In what does this... consist?
- So, according to which criteria do you...?
- Could you elaborate a little bit on what you mean by...?

3. *Could you describe to me the views of your party concerning the development of renewable energy in general and marine energy in*

particular in Scotland? How important do you think is the latter?
(question only addressed to politicians)

4. *Do you have to collaborate with people in order to fulfil your responsibilities?*

Probes, prompts and follow-up questions:

- So, could you please tell me if there were any problems in this collaboration and how you overcame them?
- And how many people would be necessary to develop this...?

Questions about the innovating process

1. *Could you describe to me how this collaboration was formed and how it works? Who took the initiative, how it started...*

2. *Could you tell me why it is important to develop a relationship with clients and what characteristics this relationship should have?*

3. *Could you please tell me why it is important to communicate with other educational organisations?*

4. *Which is the most important contribution of your organization to the Scottish economy and the sector of marine energy technology? What do you think makes it important and why?*

Probes, prompts and follow-up questions:

- Why do you think the utility companies do not harness these opportunities and, hence, it is necessary for the... to contribute?
- So, do you think that this is what renders the participation of the public sector necessary?
- Do you agree that Marine Scotland is playing a balancing role between industry and the environment?

5. *Why is it necessary for this..., to be presented and to be interesting to the general public?*

Probes, prompts and follow-up questions:

- Do you think that the public is hostile to funding research?

6. *Could you describe to me your involvement in this contribution? What do you think makes it important and why?*

Probes, prompts and follow-up questions:

- And are you happy simply because...?
- When you say..., what do you mean?

- Could you elaborate a little bit on the reasons for these different views on innovation?
- So you said that nobody did... Why do you think this is?

7. *Why do you think it is important that the benefits go to communities and not to other institutions?*

8. *What do you think would make the... more commercial?*

9. *How did you come up with the idea...?*

Probes, prompts and follow-up questions:

- But why this exact project and not something else?

10. *Could you describe the order of the actions you take when you want to complete a specific task?*

Probes, prompts and follow-up questions:

- Is it a type of brainstorming?
- How do you complete the planning and coordination of other people in research?
- And if this... doesn't make sense, what do you do?

- Could you describe to me a little bit about this feeling that "You know"? is it something that you can get with work or is it something that you just feel?
- And has this capability to feel when something is right developed over the years or was it something that you had from the very beginning?
- But why do you think you have this capability? Is it a matter of experience, is it a matter of personal talent?

11. *And is it different to work with this... instead of that...?*

Probes, prompts and follow-up questions:

- Do you think that the one is more important than the other?
- Are errors common in this procedure?

12. *How about your current working routine? How do you organize an ordinary day at work?*

Probes, prompts and follow-up questions:

- What do you do first, what do you do second, how do you proceed?
- Could you describe to me the environment in which you spend most of your time while you work?

13. *How do you handle unanticipated problems?*

Probes, prompts and follow-up questions:

- When the experiment does not go as the theory suggests, how do you try to overcome this problem? What do you do first, what do you do second?
- How do you proceed in order to find this... that you need?

14. *Do you think that your past employment and education helped you adapt in your current employment?*

Probes, prompts and follow-up questions:

- What was the most important thing that you learned during your past employment and education?
- So, how did you find adapting in your current employment? Which part of your responsibilities was the most difficult to master and which part was the easiest?

15. *Could you tell me which are the key ingredients of success in your current employment?*

Probes, prompts and follow-up questions:

- Could you elaborate a little bit on the culture? What do you mean by it?

- What is the most important factor that determines if you will succeed in this or not?

16. *Could you please tell me how it would be possible to further facilitate your work*

Questions about the organisation of the field

1. *What do you think is the greatest problem in your sector that a... has to overcome in order to succeed?*

2. *Has the function of your organization affected the development, affected the development of marine energy technology? And in which ways?*

Probes, prompts and follow-up questions:

- Why then did you decide to start your answer by saying that you affected marine energy technology marginally?

3. *Do you think that it is better if somebody has the experience of working or studying in another sector or country or do you think it is better if he is specialized in the Scottish renewable energy industry?*

4. *Could you please describe to me the problems of the marine energy sector in the UK? How do you think it would be possible to solve them?*

Probes, prompts and follow-up questions:

- Why do you think there is this mentality in the UK?
- How do you think it would be possible to change this mentality?
- Could you elaborate a little bit on what you mean by the word strategic view?
- Why do you think this culture exists?
- Why do you think there is this difference in the amount of money and of notation given by Scotland, compared to the government of Germany?
- Why do you think there is this shortage of funding from the private sector?
- And why do you think there are not yet commercial wave devices. Is it a purely technical problem?
- And why do you think the UK was so bad at commercialising all these years?
- And why do you think that firms are discouraged and they have to be encouraged. Why do you think they have this mentality?
- Why do you think there is no code of standards yet?

5. According to the document, "A Guide to Marine Licensing" of the Scottish Government a new feature of the marine licensing system is that decisions will be taken in accordance with relevant marine planning documents. The marine planning documents include the UK Marine Policy Statement and in due course the Scottish National Marine Plan and the Scottish Regional Marine Plans. Do you think that this new feature is necessary? If yes, why do you think Scotland should have a national marine plan and regional marine plans? If not, why do you think the Scottish Government chose to develop such plans?

Probes, prompts and follow-up questions:

- But why do you think there is this may be not so correct focus?
- Could you tell me why do you think there is this top-down approach?

6. Which approach would you consider more effective for the development of marine energy? Rapidly scaling towards multi-megawatt devices or using a more patient, modest approach?

Probes and Prompts:

- Why do you think that other marine energy developers are focused on rapidly scaling up to multi megawatt devices?
- And why do you think this is a longer term objective?
- But why do you think there is this pressure to upscale quickly?

- But, how it would be possible to arrive at this very low cost? And do you think that large multi-megawatt developments would be preferable or may be a more patient approach?
- So, you think that the harsh conditions of the environment mean that a cautious approach is more necessary?

7. *Do you think that it is better for the natural heritage of Scotland to develop marine renewables one step at a time or to go immediately to large scale production of marine energy?*

8. *You argue that the wider UK energy system remains substantially oriented to market competition and efficiency. Did this orientation change during the last 5 years and if yes, why do you think? And if not, why it did not change?*

9. *And how do you think initiatives such as the Saltire Prize will eventually affect marine energy technology? Do you think that it will help Scotland succeed in becoming a world leader in marine energy technology?*

10. *According to EMEC, it seems that there is no predominant way to turn marine energy into electricity and instead there are several*

competing types of devices which consist of the following: a prime-mover element, a power take off arrangement, a reaction system and a control system. Which of the latter do you think will determine in the end which device will win this competition?

Probes, prompts and follow-up questions:

- why in the case of marine and tidal energy do you think that there will not be one winner?

11. *Could you describe to me any instances of successful work of which you are proud?*

12. *Could you describe to me the criteria according to which you decide where the... can have the greatest impact and how do you choose between program areas in order to ensure the effective use of resources and the quality of output?*

13. *Since you are simultaneously a businessman and a scientist do you think that there is conflict between these two roles? If yes, in what does this conflict consist?*

14. *How would you describe the key ingredients of a good collaboration with your colleagues? Do you think it is important that*

each employee has strictly distinct and separate responsibilities? If yes, why?

Probes, prompts and follow-up questions:

- But how about the competences? Is it important that each part of the team, each member of the team has different competences?

15. *Do you think that it is better if somebody specializes in performing a specific role, a specific task in your work or is it better if one can do a little bit of everything?*

16. *How would you describe the key ingredients of a good collaboration between the public and the private sector regarding the renewable energy industry? Do you think it is important that the private and public sectors have strictly distinct and separate responsibilities? If yes, why?*

17. *To what extent do you think a person like you should work within their particular role as instructed and to what should he/she try to be innovative?*

Probes, prompts and follow-up questions:

- But these limits, how are they defined?

- Do you think that when you started, you had more original ideas?

Open Concluding Question

1. *Anything else you think it would be useful to know about your work?*

Probes, prompts and follow-up questions:

- How would you think it would be possible to avoid making these mistakes again?
- And why do you think more people, why do you think many people don't want to work in the sector?
- Are there some parts of your work that are very different from others?
- If you had to answer how would you think it would be possible to avoid making these mistakes again?