

**CONSTRUCTING THE HYDROGEN FUEL CELL COMMUNITY: A
CASE STUDY OF NETWORKED INNOVATION GOVERNANCE**

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ABSTRACT

Hydrogen and fuel cells (HFCs) are a suite of low carbon energy technologies that are beginning to emerge as promising objects in energy and transport policy. This thesis presents the findings of an actor-centred constructivist case study into the policy community emerging around HFC innovation in the UK. Emerging at the intersection between increasingly networked forms of governance (Hajer, 2003; Torfing, 2007); energy; climate and industrial policy (Kern et al., 2014), innovation has been the focal point of literatures advocating transitions towards more sustainable socio-technical systems (Geels, 2002; Loorbach, 2010). Besides a few notable exceptions this area has been under-examined in the UK policy studies literature, and no studies have thus far focused on HFCs as objects of UK policy processes. The thesis develops an interpretivist-constructivist methodology to sketch how actor interpretations of competency and context inform the interests and strategies in innovation policy processes. Drawing on interviews with 31 members of the HFC community and extensive documentary research it argues that while innovation governance is, in part, a product of networked interactions between HFC community members, these interactions are highly circumscribed by prevailing policy paradigms. Expressed via a logic of commercialisation and empowered by the resources of large industrial firms, such paradigms operate to de-politicise governance practices and align innovation priorities around those compatible with the interests of a narrow band of large industrial interests. In so doing the thesis contributes to our understanding of interpretation as the means by which ideas and resources shape strategic interactions in policy processes, and; serves as a reminder that networked forms of governance can close down as well as open up participation in policy debate and delivery.

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1. INTRODUCTION

I. Hydrogen Fuel Cells, Network Governance and Energy Innovation Policy

Hydrogen fuel cells (HFCs) have long featured on lists of future technologies which may hold the key to reducing fossil fuel dependence, emissions of greenhouse gasses (particularly CO₂) and urban air pollutants, as well offering substantial competitive advantages to the companies and countries capable of bringing them to market early (Hoffman, 2001; High Level Group, 2003; UKHM, 2013a). Hydrogen's potential as an energy carrier; storing renewably produced energy for future use in domestic and transport settings; has led to speculation that in the future we will see the emergence of a hydrogen economy in which individuals and organisations produce and consume hydrogen according to their own needs; the trade in any surplus radically transforming access to energy resources at local, regional and global levels (Clark II & Rifkin, 2006; Dunn, 2001; McDowall & Eames, 2006; Rifkin, 2003). In the present we have seen a growing interest from policy makers in harnessing HFC technologies within broader decarbonisation and transport strategies. In particular the technology has been identified for its potential to enhance the economic competitiveness of Europe and the UK's automotive, high-tech research and manufacturing industries (HM Government and Automotive Council UK, 2013; Kemp-Harper, 2011; BIS & DECC, 2009). HFCs have been hailed for their capacity to reduce carbon emissions from domestic electricity and heating and transport sectors, and; help balance the strain of growing levels of intermittent renewable electricity generation (CCC, 2010; DTI, 2004; DECC, 2011; High Level Group, 2003).

Research continues apace in the physical sciences and a growing body of social science literature is emerging looking to likely issues of economic viability (Balta-Ozkan & Strachan, 2010; Dodds & Hawkes, 2014); potential routes to market; system designs (Eames & McDowall, 2010; Ekins & Hughes, 2009; 2010a; Hardman, et al., 2013); as well as issues of public acceptance and risk perceptions of hydrogen production, transport and refuelling (Cherryman, et al., 2009; Ricci, et al., 2010; Sherry-Brennan, et al., 2010). However, to date we have seen no studies of HFCs as objects within UK and European policy processes, nor have we seen a sustained study of the broader policy network or community engaged within such processes. As a technology with potentials across multiple

policy domains for energy, innovation and transport; HFCs offer an interesting case study for students of the policy process.

As objects of policy, HFCs have appeared in government discourse in two ways; as a single technology being funded through emergent institutional arrangements for energy innovation, and; as part of a wider grouping of emergent low carbon technologies posing distinct infrastructural, market and regulatory challenges if they are to provide a significant contribution to the UK economy or carbon reduction targets. To this end we have seen the emergence of a plethora of research networks and public private partnerships around the technology. Spanning local, national and European levels of governance, these networks comprise policy makers, private businesses and researchers, aiming to enhance the UK's capabilities in HFC research development and manufacturing; establish goals and priorities for future research, development and demonstration (RD&D) funding; and shape the development of future infrastructure, market and regulatory development (for a brief, non-comprehensive overview see; UKERC, 2014). As such, we may begin to think about HFC innovation governance in terms of a policy community, or network in which non-state actors are being increasingly incorporated into policy design and delivery.

Since the 1990s we have seen the emergence of a substantial literature arguing that we are witnessing a shift away from centralised state decision making toward new modes of governance which seek to incorporate the knowledge; expertise; and implementation capacities of a broader network of actors from the private sector and civil society (Hajer, 2003; Rhodes & Marsh, 1992; Rhodes, 1996; Sørensen & Torfing, 2009). While early network governance theorists suggested this may amount to little more than an ideologically motivated 'hollowing out of the state' (Rhodes, 1996, pp. 661-663), others have emphasised the democratic potential and new capabilities offered by networked forms of governance (Hajer & Wagenaar, 2003; Torfing, 2007). In this sense, network governance processes can be viewed as practice oriented, taking their starting point from a shared

policy domain to seek mutually agreeable problem definitions and actions for its navigation. Thus modes of governance such as public-private partnership, privatisation and service commissioning operate to harness the differentiated skills and expertise of the state ; private companies; NGOs and independent regulators in relation to a particular task, be that in the delivery of healthcare services or large infrastructure projects (Flinders, 2005). Similarly, proponents of more deliberative modes of policy making suggest that by incorporating expert and stakeholder views through networked deliberation, the processes and outputs of policy making can be enhanced (Skostad, 2003; Hoppe, 2011). Governance by networks has thus increasingly come to be seen as a means of filling 'institutional voids' (Hajer, 2003), spaces in which states lack either the capacity or legitimacy to govern alone.

In energy and innovation policy we have seen these shifts present in the move to energy market liberalisation in the 1980s and 1990s, as well as more recent efforts to develop public bodies and institutional structures capable of fostering the delivery of new technologies, infrastructures and regulatory regimes to accelerate shifts towards more sustainable forms of economic development (Kemp, et al., 2007; Loorbach, 2010; Schot & Geels, 2008). Theorists of transitions management and environmental political economy argue for such transitions to be successful , close coordination is required between incumbent businesses; regulatory regimes and the proponents of emergent technologies is required to prevent emergent technological pathways from being closed down (Kemp, et al., 2007; Meadowcroft, 2005).

In the Netherlands, where transitions management theory has been explicitly incorporated into policy design, a growing body of literature has emerged covering the practical challenges of incorporating smaller technology communities into policy architectures. In particular such approaches have been problematized for their failure to anticipate and mitigate pre-existing imbalances of power between proponents of niche technologies and incumbent industries . In

particular these critiques focus on how pre-existing policy discourses and entrenched interest groups have restricted opportunities for radical challenges to existing socio-technical regimes to emerge (Kern & Howlett, 2009; Smith & Kern, 2009; Shove & Walker, 2007). Reflecting similar critiques emerging from reflexive ecological modernisation theory (Christoff, 1996; Hajer, 1996); such authors argue that in relying on relatively narrow ranges of technologically informed actors; innovation policy networks have tended to avoid focus on large scale socio-technical transformations, reproducing incremental innovation programmes favoured by dominant energy system actors (Scrase & Smith, 2009) . In these accounts, the process of innovation governance comes to resemble phenomena of de-politicisation or 'governance in the spirit of capitalism' (Eagleton-Price, 2014, p. 5; Sørensen & Torfing, 2005; Swyngedouw, 2005; Wood, 2015), through which contestable economic, environmental and political arrangements become reified and positioned beyond democratic control.

While there is a growing literature on UK energy innovation policy, to date its primary foci have been the challenge of shifting existing regulatory and investment architectures to incorporate new generators and technologies and accommodate greater operational flexibility (Bolton & Foxon, 2015; Foxon, et al., 2005; Helm, 2007). Operating at systems level, attention has been paid to the emergence of a somewhat fragmented system for the management of energy innovation (Winskel, et al., 2014; Winskel & Radcliffe, 2014); as well as singular institutions and policy trajectories (Kern, 2012; MacKerron, 2009). Alongside this literature is a broader ongoing debate as to whether the turn towards innovation and reorientation of energy policy towards issues of security and decarbonisation constitutes a paradigm shift away from the discursive-institutional framework of market liberalisation (Fudge, et al., 2011; Helm, 2007; Kern, et al., 2014). While the former may be thought of as a relatively small network of energy companies; regulators and government departments, the latter may come to comprise a far wider array of technology companies; domestic and local authority energy producers; as well as those actors currently dominating the UK energy system (Mitchell, 2008).

However, to date relatively little attention has been paid to the interactions between the emergent institutional architecture and paradigm for energy innovation policy, and the community of actors involved in innovation governance in the UK. While approaches to network governance and transitions management have variously described such communities as means for the expertise of non-state actors to inform democratic policy deliberation or new routes for established interests to maintain their power and position, we simply do not know which may be the case within UK energy innovation policy. Given the current status of HFCs as a niche low-carbon technology, a study of the policy community emerging around them may thus offer significant insight into the role of power and interests within this ongoing paradigmatic shift, and how this shift is effecting the interests and strategies of actors at the interface of UK energy and innovation governance. Given the lack of attention to date on this area in general and on HFC innovation in particular, such a study of has the potential to be of interest both in its own right, and for what it may tell us about the broader policy process drawing together energy, innovation and transport policy to promote emergent low carbon technologies.

II. Research Position and Overview

This thesis approaches the topic of HFC innovation governance from a perspective Saurugger describes as 'actor centred constructivism' (ACC). The product of a fusion between rational choice institutionalist perspectives and newer forms of constructivist institutionalism; ACC accounts view governance processes as the product of strategic interactions of social actors for whom ideas represent a strategic tool for realising their interests. This is not to say such interests are materially determined, rather they are themselves shaped by an actors' position within and rational interpretations of the broader material, ideational and institutional structures in which they are located (Hay, 2011). While rooted in accounts of the policy process emphasising the role of

institutional socialisation (Dowling & Pfeffer, 1975; March & Olsen, 1989; Meyer & Rowan, 1977); social learning (Bennett & Howlett, 1992; Hall, 1993; Hoppe, 2011); and discourse (Glynos & Howarth, 2008; Schmidt, 2008); ACC seeks to situate policy process at the level of strategic relations between rational social actors. In so doing, ACC accounts provide a means to examine how and why particular ideas do or do not gain broad acceptance in policy discourse, institutional paradigms and the rules and standard operating procedures of particular institutions (Saurugger, 2013).

As a policy network negotiating issues pertaining to highly rational, techno-scientific questions (which nonetheless carry economic-material and ideational implications in terms of their capacities and claims for carbon reduction and boosting corporate and international competitiveness), the HFC community appears an ideal case for analysis within an ACC framework. In so doing, the thesis aims to identify both the limits of more ideationally informed accounts of the policy process; while at the same time highlighting how ideas and policy discourse operate to shape and guide how rational, materially constrained actors interpret their interests and construct strategies for negotiating complex policy problems. More specifically the thesis will be guided by the following questions:

Research Questions

1. Actors
 - a) Who are the key actors in the UK HFC community?
 - b) How does position in relation to existing socio-technical regimes effect actor strategies?
2. Institutions
 - a) What roles do ideas play in shaping how HFC community actors interpret and construct their interests?
 - b) What formal and informal institutions allow for social learning and the identification of collective interests in UK innovation governance?
3. Policy

- a) What do the strategic interactions of HFC community actors tell us about the process of governing innovation networks?
- b) How should HFC innovation governance in the UK be characterised

Thesis Overview

The opening chapters of this thesis discuss literatures on HFCs; science and technology studies; constructivist approaches to policy analysis as well as research in the substantive field of energy and innovation policy. Chapter 2 provides some important background to HFC technologies, providing a basic outline of the current state of the technology; the roles for which they have been proposed in various areas of the energy system; and a very brief overview of the public funding arrangements through which the UK and EU have sought to support HFC innovation. Chapter 3 pulls back from this technological specificity to provide an overview of two broad disciplines of relevance to the study of innovation policy networks and communities. Providing a brief overview of rational choice and sociological approaches to these disciplines, the chapter then shifts its attention to constructivist approaches to STIS and policy analysis. In particular, the chapter draws attention to transitions theory's distinction between socio-technical niches, regimes and landscapes (Geels, 2002; Schot & Geels, 2008); and actor centred constructivist approaches to ideas, institutions and strategies (Hay, 2011; Saurugger, 2013) as valuable concepts for making sense of contemporary debates over energy innovation. Following on from this, the chapter explores more substantively focussed literature tracing ideas of energy market liberalisation and decarbonisation in UK energy and innovation policy (Helm, 2008; Kern et. al., 2014; Winskel & Radcliffe, 2014). In so doing the latter part of this chapter shifts to the roles of ideas and interest in shaping the priorities of energy and innovation policy (Lehtonen & Kern, 2009; Mitchel, 2008; Scrace & Smith, 2009), pointing to this as a key area from which research into HFC innovation governance should depart.

Chapters 4, 5 and 6 set out the process through which the research progressed. The opening of chapter 4 follows Yanow & Schwartz-Shea (2006) in challenging the notion that questions of research design and methodology can realistically be separated from core questions of ontology, arguing instead that our understanding of the world necessarily impacts upon the means by which we seek to investigate it. From this it outlines how a constructivist-interpretivist focus on contextualised interpretation and strategic agency provides the best means of conceptualising the meaningful interests and relations between members of the HFC community. Having done so, the chapter moves to discuss the HFC community as a geographically dispersed community of interest, the boundaries of which were uncertain at the outset of the research. In so doing, this chapter outlines case study research as the design best suited to identifying and explaining the emblematic range of interpretive positions within such a community. Finally the chapter discusses what the study claims to offer in terms of knowledge of the HFC community and transferability to other cases of networked innovation governance, highlighting interpretivist concepts of credibility and transferability grounded in rich contextualised description, as the key criteria against which the research should be judged (Flyvbjerg, 2011; Lincoln & Guba, 1985; Schwartz-Shea, 2006).

Chapter 5 details the methodology and rationale for collecting data in the form of public domain documentation and interview accounts. Data collection aimed to identify both the emblematic forms of variation between different organisations within the HFC community, and examine the ideas and rationales giving rise to this variation. The chapter outlines the process of snowball sampling through which documents and initial interviews gradually honed in on organisations, based within wider collaborative networks as the key case units through which the overarching case of the HFC community could be described. The remaining methodological discussion in this chapter focuses on the status of documents as indicators of the institutions and strategic positioning affecting an organisation (Fairclough & Thomas, 2004; Tracy & Tretheway, 2005), and interviews as negotiated texts (Holstein & Gubrium, 1995; Silverman, 2001). Providing an overview of the construction of

interview topic guides and conduct of interviews in practice, this discussion focusses on the processes of co-construction, reflexive interpretation and member checking through which the research was able to establish rich, credible accounts of organisational strategies and interpretations.

The final methodologically oriented chapter focuses on the interpretivist-constructivist analytic strategy through which interview and documentary texts were interrogated. The early stages of this chapter describe how three stand out elements emerged through which the researcher oriented themselves to the data; actors, institutions and strategies. In making sense of these elements, the chapter draws heavily on Yanow's (1996; 2000) model of interpretive policy analysis focussing on narratives; metaphors and categories. Bringing these insights together with insights from actor centred constructivism (Hay, 2011; Saurugger 2013), Chapter 6 outlines the iterative development of three analytic tracks corresponding to actor narratives; intersubjectively recognised categories and metaphors; and collective practices and strategies, which provided the basis for the eventual development and presentation of research findings.

Beginning discussion of the research's findings, Chapter 7 outlines the key types of actor presently constituting the HFC community: research institutes; pre-commercial firms; enthusiastic and cautious incumbents and early movers. Differentiated by their techno-scientific and economic competencies; interpretations of the environmental, resource and market landscapes they face, and; the meaningful interests they identify for HFCs, these actors nonetheless are all members of overlapping institutional networks for HFC innovation governance. In particular this chapter identifies claims to techno-scientific expertise and objectivity; industrial impact; market opportunity and risk; and environmental imperatives as central to the ways different types of actor have sought to identify and engage with HFCs. Developed through analytic conversation between transitions theory approaches and constructivist policy literature, this typology provides the first formal description of the HFC policy community in the UK.

Chapter 8 outlines the broad institutional landscape in which HFCs are emerging as an object of energy and innovation policy in the UK; comprising a range of departments, public bodies, public private partnerships and projects each operating one step closer to the HFC community itself. While the thesis has sought to maintain focus on the UK, no discussion of the policy networks of the British HFC community would be complete without reference to the European Fuel Cell and Hydrogen Joint Undertaking (FCHJU), a public private partnership that remains the largest funder of UK HFC innovation. Although each of these institutions carry distinct institutional identities and remits; they are bound by a common logic of appropriateness (March & Olsen, 2004; Saurugger, 2013), within which commercialisation is positioned as the ultimate goal of innovation governance. While this logic operates in part to legitimise state intervention into liberalised markets; at the same time it serves to privilege industrial organisations in the development of RD&D priorities and goals and limit the roles policy actors may take in promoting innovation. Finally in exploring this logic, the chapter points to several institutions in which the commercial competencies favoured by incumbents come to function as exclusionary criteria for participation in funding prioritisation and regulatory planning.

Chapter 10, turns its attention to the means through which it has become possible to speak of an HFC community in general terms; looking to the intersubjectively recognised practices and actor strategies present within the HFC policy community. In so doing it identifies two processes; one characterised as relatively inclusive process of network formation, the other more exclusionary. In the former, conferences and project participation appear as forms of network constitution through which actors with diverse competencies come together in order to achieve collective goals in relation to the development of HFC activities. While these sites are to a degree competitive and can function as risk management strategies for incumbents they are in general relatively open to different actor types. Funding deliberation and lobbying activities conversely have tended to operate on a more exclusionary basis. While not necessarily deliberate, this chapter points to several instances of

institutionalised deliberation operating to exclude actors lacking the organisational resources to engage on a regular basis; forcing early movers and pre-commercial firms to adopt strategies of selective or dis-engagement. Finally the chapter discusses a range of individual and collective practices of evidence production and industry body formation in efforts to influence future regulations and incentives for HFC technologies. In so doing it focuses on the collective interpretations that technocratic ideas of energy system optimisation in alliance with other technologies provides the most favourable means of garnering policy support.

In concluding the thesis, Chapter 10 draws the research findings back to the thesis' preceding discussion of transitions theory and constructivist policy analysis. In so doing draws attention to how the constructivist concept of contextualised interpretation can contribute to our understanding of how actors interpret their interests in relation to niche, regime and landscape interactions. Its discussion then shifts to the logic of commercialisation as an illustration of how the contemporary bricolage of market liberalisation, innovation and decarbonisation energy paradigms function to shape the practices of policy actors and the structures of innovation policy actors and networks. Finally it suggests that given its relatively narrow, technocratic orientation; the HFC community has tended to orient itself toward the preferred technologies and innovation priorities of incumbents.

2. BACKGROUND: HYDROGEN AND FUEL CELLS IN ENERGY & INNOVATION POLICY

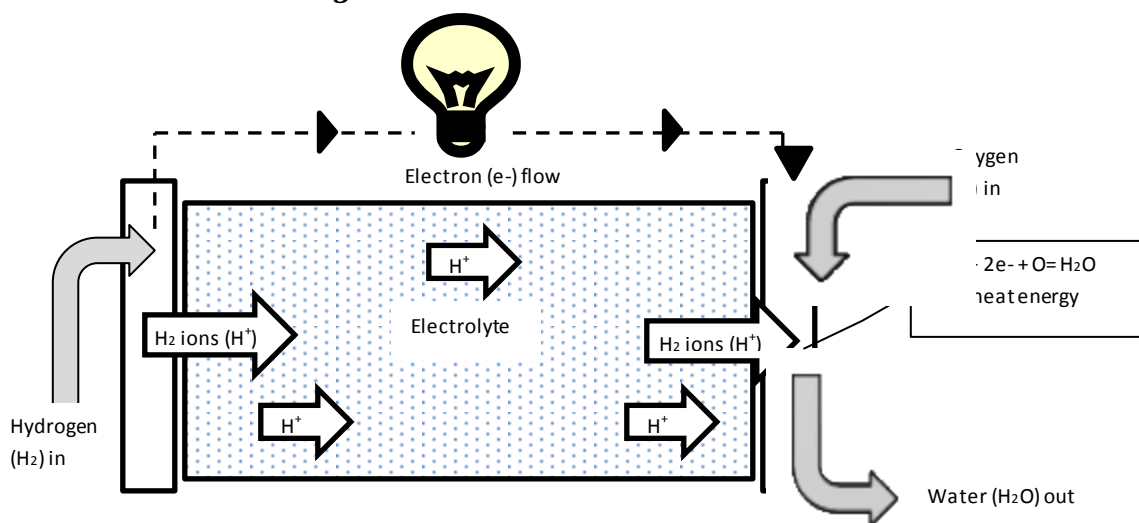
III. Some basic chemistry: HFCs as artefacts

Prior to beginning a fuller discussion of HFCs and the wider policy context in which they are taken, it is first necessary to provide a brief introduction to the technology. In the first instance we must distinguish between the two terms 'hydrogen' and 'fuel cell'. Hydrogen, generally signified through the chemical designation H_2 , is the most abundant element in the universe, comprising approximately 80% of all matter. Comprising a single proton paired with a single electron, H_2 is highly reactive and as such only occurs naturally on earth bonded to other atoms in tightly formed molecules, the best known of which include water and hydrocarbons such as coal, mineral oil and natural gas. When oxidised, usually through combustion, other elements within these fossil fuels form the greenhouse gas CO_2 , as well as a range of other harmful pollutants such as carbon monoxide (CO) and sulphur dioxide (SO_2). Furthermore the heat produced by the combustion process also leads to the reaction of oxygen and nitrogen present in the air to form nitrogen oxides (NO_x) (Momirlana & Veziroglub, 2005). In contrast, when hydrogen is oxidised alone the only products are water and energy, released by the breaking of chemical bonds between the reacting molecules, plus small quantities of NO_x from the heat of combustion. During combustion this energy takes the form of light and heat, however if the reaction is conducted electrochemically (through the input of electricity rather than heat), the energy released will be electrical with no NO_x produced. This is not to say H_2 is necessarily a zero carbon fuel, rather this depends on the production technique employed, either through its separation from fossil fuels through industrial processes such as steam reformation, or via electrochemical splitting of water into its component gasses hydrogen and oxygen. While the former process remains by far the most economical, it releases carbon and other pollutants, just as direct combustion would. Carbon capture and storage technology (CCS), should it prove viable, may hold out the potential of capturing such emissions at centralised production plants, preventing their contribution to climate change (Hoogers, 2003; Hart & Bauen, 2003). Electrolysis on the other hand, if powered by renewable electricity, is a zero carbon process. It

is hydrogens combination of high energy content with the potential for the capture or elimination of carbon emissions that provide the primary rationale for its use as a fuel.

Fuel cells (FCs) conversely are entirely human artefacts, assembled by human hands for a specific purpose. In essence a fuel cell is a device for generating electricity through an electrochemical reaction between a pure or hydrogen rich fuel and oxygen in the air. All fuel cells comprise two electrodes; a cathode and an anode, separated by an electrolyte (see figure 1):

Figure 1: Basic Fuel Cell Design



The fuel enters the fuel cell at the anode, where a catalyst separates its hydrogen component into negatively charged electrons and positively charged ions. While the ions are capable of passing through the electrolyte barrier between electrodes, the electrons are diverted around an electric circuit to power a load, which depending on the size of the fuel cell can vary from a small light bulb to a bus or even a large industrial plant. At the cathode, oxygen from the air reacts with the incoming electrons from the circuit and ions that have passed through the electrolyte to form water and a small amount of heat (Busby, 2005). When fuelled by fossil fuels, additional chemicals present in the fuel such as carbon and sulphur are partially reformed into hydrogen either within the fuel cell itself or in an external reformer with excess pollutants emitted into the atmosphere as CO, CO₂ and SO₂. However because the electrochemical reactions in FCs produce less kinetic, sound and

electromagnetic (light) energy, the process can be vastly more efficient than combustion (Hart & Bauen, 2003; Karimi & Foulkes, 2002). This means that even when powered by fossil fuels, FCs may offer a cleaner more resource efficient means of energy generation than burning fuels in engines or furnaces to drive turbines.

IV. HFC Rationales: Rising prices, Scarce Resources & Emissions Reduction

The UK energy system is undergoing a period of profound change with a range of concerns linked to the cost of energy; the long term availability and security of access to fossil fuels; and climate change all present in contemporary energy policy discourse (Helm, 2005; Scrase & Ockwell, 2009). While the politics and discourse emerging around such policy will be examined more critically later in Chapter 3 (p.54), this section aims to provide a more technical discussion of those elements of UK energy policy discourse that are of most relevance to HFC technologies and their advocates. There are two broad reasons for doing this. Firstly the technological policy problematisations outlined here provide some contextual background for why HFCs have begun to appear as objects of governance. Secondly in placing the technocratic problematisations relatively early in its discussion, the thesis mirrors the priority given to these accounts in the writings of HFC advocates (cf. Ball & Weitschel, 2009; Busby, 2005; Ekins, 2010a). In particular this section highlights the domestic energy and transport sectors as essential components of contemporary UK decarbonisation policy, likely to require new innovations across a range of emergent technologies for energy generation, storage and transmission.

Domestic energy use and transport combined comprise over half of overall energy demand in the UK. Domestic energy consumption is overwhelmingly fulfilled via electricity and natural gas and meets 29% of primary energy consumption in the UK, with transport contributing a further 27%. Despite some reductions attributed to rising household and engine efficiency standards, and shifts from coal and petrol to natural gas and diesel; these two sectors remain major contributors to UK CO₂

emissions (MacLeay & Annut, 2013; Prime, et al., 2014). Road transport, particularly by private car comprises the bulk of the transport sectors 23% contribution to total UK greenhouse gas emissions. Residential use of electricity and gas are responsible for a further 25%, and in both cases carbon dioxide (CO₂) from fossil fuel combustion is by far the largest component (DECC, 2014a).

In light of the stated intentions of the UK government and European Union (EU) to drastically reduce such emissions, further changes in these sectors are likely to be required. The EU's targets for CO₂ reduction include 20% increases in renewable generation and energy efficiency by 2020, and it's 2007 Strategic Energy Technology Plan explicitly links long term economic development and growth to low carbon innovation (Carvalho, 2012). The UK's Climate Change Act (2008) enshrines in law the target of reducing CO₂ emissions by 80% from 1990 levels by 2050; to be achieved through a series of five year carbon budgets which set legal caps on emissions over each period. The first four carbon budgets have now been agreed by the statutory Committee on Climate Change (CCC) and signed into law, with the intention to achieve 50% reductions in emissions by 2027. Such reductions are thought likely to require almost complete decarbonisation of electricity generation by 2030 and 44% reductions in emissions from surface transportation. By 2040, all new vehicles sold are expected to be ultra-low emission vehicles, which in practice means they will run on electric, fuel cell or biofuel drive trains (CCC, 2010; HM Government, 2011).

Domestic heating, one of the more difficult sectors to decarbonise due to the prevalence of natural gas in residential space and water heating, is expected to proceed more slowly. Efficiency measures such as insulation comprise the main source of anticipated emissions reductions to 2020, after that decarbonisation is anticipated to require shifts to more efficient transitional technologies such as heat pumps and combined heat and power (CHP), with low-carbon electrification expected to be the

end goal (HM Government, 2011; DECC, 2012a). Given the uncertainty inherent in such long term projections, based on energy systems modelling and a series of assumptions ranging from future commodity prices to rates of technological development, these forecasts are to be taken with a degree of caution. However, if the broad goals of decarbonisation are to be met, large scale changes of the UK energy system will be required.

In electricity generation the intermittent nature of wind energy, expected to expand vastly in the period to 2050, poses particular problems. In the first instance changing wind speeds mean the output of such capacity is unstable. This poses a problem for ageing transmission networks designed for the relatively predictable and stable outputs of fossil fuel and nuclear generation. The inflexibility of wind is likely to necessitate new mechanisms for energy storage to act as a sink for excess generation in periods of low demand, and additional generating capacity to cover windless periods and times of peak electricity use. If transport and domestic heating are also likely to be increasingly electrified, this will exacerbate the need for additional (likely intermittent) renewable generating capacity and new technologies to balance their strain on the grid (CCC, 2010; Cavallo, 2007; DECC, 2012a; Helm, 2005). In the period to 2020, conventional grid management technologies, domestic energy efficiency enhancements and new diesel and hybrid engines are likely to play the predominant balancing role; in the decades following a range of new technologies are thought to be required. A number of options have been proposed to meet these challenges; from offshore wind to ground source heat pumps; centralised nuclear based energy networks to decentralised 'smart' grids sharing locally generated heat and power.

Dovetailing with the decarbonisation imperative are notions of energy security which construct the UK's dependence of electricity and gas as in some way under threat (for discussion see; MacKerron,

2009; Scrase & Ockwell, 2009). North Sea reserves of oil and gas are diminishing. The UK has been a net importer of both fuels since 2006 with production in 2013 down to approximately a third of its peak in 1999/2000 (DECC, 2014b). This depletion combined with fears over the stability of oil and gas supplies in Russia and the Middle East and increased demand from rapidly industrialising states have contributed to a partial reframing of UK energy policy as a national security issue; reaching its highest point in the 2007 Energy White Paper which foregrounded security of supply as necessitating expansion of nuclear and renewable energy production and increased efforts in demand reduction (DTI, 2007, p. 7; Scrase & Ockwell, 2009). The 2011 White paper, while less concerned with international threats has likewise identified security of supply as a primary concern, this time rearticulated to cover the need for investment in the expansion of new low carbon electricity generation and transmission capacity, and the affordability of these systems (DECC, 2011). Household electricity and gas bills have been rising consistently since 2004, and did so by 79% and 121% respectively in the period to 2011. While the bulk of these increases have been attributed to rising wholesale gas prices; infrastructural investment, investment in renewables, and rises in VAT have also contributed. These costs are projected to continue to rise in the period to 2020, partially as a result of predicted increases in offshore wind generation (CCC, 2011, p. 16; Bolton, 2014, pp. 11-13).

Current markets, future potentials

As a technology still in its infancy, there is as yet no mass market for HFCs, nor are they a common referent in energy policy discourse. Rather, private sector designed and manufactured HFCs have tended to find use in publicly subsidised demonstrations or small markets where an aspect of the technology justifies a price premium. That being said, markets are beginning to emerge for HFCs, with industry reviews tracking substantial expansion in fuel cell sales over the past five years (Carter & Wing, 2013). While conceptually speaking, HFCs are often discussed in as a single technological

category, there are a number of distinctions within this which tend to be used to characterise the technology according to fuel cell type (generally the electrolyte material), and application. Fuel Cell Today, a major industry publication and authors of the most authoritative review of the sector divides its analysis according to three such application areas; ‘portable’; ‘stationary’ and ‘transport’, each representing different markets, and different types of fuel cell technology (Carter and Wing 2013, p.4, see also; Busby, 2005, 12-13, 102, U.S. Department of Energy, nd). The following table presents global fuel cell sales by application, taken from Fuel Cell Today’s 2013 Industry Review:

Table 1: Global Fuel Cell Sales by Application in Megawatts and ‘000s units sold

Applicat- ion	2009		2010		2011		2012		2013	
	MW/’000	units	MW/’000	units	MW/’000	units	MW/’000	units	MW/’000	units
Portable	1.5	5.7	0.4	6.8	0.4	6.9	0.5	18.9	0.3	13
Stationary	35.4	6.7	35	8.3	81.4	16.1	124.9	24.1	186.9	51.8
Transport	49.6	2	55.8	2.6	27.6	1.6	41.3	2.7	28.1	2

Adapted from: Carter & Wing (2013, pp. 42-43)

These figures show physical deployments in stationary and transport applications as the largest subsectors of the fuel cell industry by system size (MW), significantly outstripping usage in portable power applications. The disparity between these figures and the relatively high numbers of units for portable applications shipped is attributable to the smaller size of portable units, and their status as earlier to market technologies in mobile battery charging and off grid leisure activities (Carter & Wing, 2013). It is however energy and transport which comprise the most significant segments in terms of MW units at present. Moreover, given these sectors are also the most significant emitters of GHGs, over the long term energy and transport are thought to represent the largest and most beneficial potential markets for HFC technologies.

In particular it is the potential of HFCs to facilitate the integration of renewables and decarbonisation of ‘tricky’ sectors such as domestic heating and transport where electrolysis; fuel cell CHP and hydrogen transport technologies can make the most of their efficiency advantages over incumbent

technologies. Electrolytic production of H₂ has been proposed as a means of storing excess electricity generated by intermittent renewable generation for subsequent use in modified gas turbines or transport refuelling. H₂ has also been proposed as a heating fuel that could be injected in small proportions of H₂ into the natural gas grid, or over the longer term through full conversion of grid to pure H₂ (Moriarty & Honnery, 2007; Korpåsa & Greiner, 2008; Ehteshami & Chan, 2014).

As a more transitional measure, fossil fuel powered Solid Oxide and high-temperature Proton Exchange Membrane fuel cell (SOFC & PEMFC) technologies have been proposed for use in micro-CHP (mCHP) applications; using natural gas from the existing grid to generate electricity and heat for use in homes and small businesses. More efficient than conventional boilers or engine driven CHP technologies, fuel cell mCHP may represent a transitional technology, reducing use of natural gas through more efficient energy conversion and eliminating efficiency losses in the transmission of electricity from power plant to end user. Additionally, were sufficient fuel cell mCHP units to be installed, their combined generating capacity has the potential to displace demand for additional power plant construction and attendant enhancements to the electricity transmission grid, decentralising electricity generation to a network of household mCHP producers exporting their excess generation to the grid (Hawkes, et al., 2009; Dodds & Demoullin, 2013). While at present this last scenario may seem exotic, the shift towards more responsive electricity metering and smart grids is designed in part to facilitate such forms of micro-generation.

In transport a coalition of major automotive manufacturers, including several with significant manufacturing presence in the UK, have announced plans for the introduction of low temperature PEM powered fuel cell electric vehicles (FCEVs) worldwide from 2015 (Daimler, et al., 2009). While in the early stages much of the hydrogen used will be produced from existing sources and steam

methane reformation, the public-private partnership UK H₂ Mobility (2013a, pp. 10, 19-22) estimates that by 2030 51% will be produced using electrolysis powered using intermittent renewables, providing a secondary market or excess wind electricity that would otherwise be constrained off the grid.

Given the range of potential markets and energy policy drivers for HFC development, there is a growing and diverse industry emerging around HFC technologies in their various forms (Carter & Wing, 2013). This industry encompasses firms of varying sizes from established multinational automotive and energy companies to small start-ups specialising in particular aspects of HFC technology, and is supported by an active and growing academic research base. While somewhat unstable with firms entering and leaving the sector at regular intervals, industry commentators remain optimistic that HFCs are due for significant market breakthroughs in the coming years and decades (Carter & Wing, 2013; E4Tech, 2014). Offering potential storage and use vectors for domestically produced, intermittent renewable energy HFCs may; facilitate decarbonisation and diversification away from hydrocarbons in transport fuels; help avoid additional investment in transmission infrastructure; and provide other benefits in terms of economic growth to states gaining an early lead in technology development and deployment (E4Tech Energy, et al., 2004; High Level Group, 2003; UKHM, 2013a). While these benefits remain potential, reliant on a variety of factors including cost reduction, they have contributed to the development of some early markets, and speculation regarding their future growth. The identification of these markets; combined with the technologies potential to help meet broader energy policy objectives has led to HFCs gradual recognition as objects of governance.

HFC Futures: Teleology to Transitions

There is a strong trend in much of the literature emerging around HFC technologies that paints their emergence as part of an inevitable process of human progress, in which human beings inevitably shift from high to low carbon forms of energy generation. In this literature high carbon combustion of wood, gives way to coal, oil and natural gas; at each stage the carbon content of the fuel source declining. The next logical step for these authors is the abandonment of hydrocarbon based fuels to pure hydrogen itself. Thus for Busby:

‘Hydrogen represents the end point of humanity’s trend towards using less and less carbon - a trend that has persisted throughout our history of consuming fossil fuels and for thousands of years before that, if you count our ancestors burning wood, peat and dried-out animal waste’ (Busby, 2005, p. 6).

While the above extract is somewhat unrepresentative of Busby’s more nuanced appraisals of the prospects for specific HFC technologies, the above statement is reflective of a broader literature that represents the technology as an engineered route to *The End of History*; delivering the world to a promised land of ubiquitous, cheap and renewable energy (Dunn, 2001; Rifkin, 2003; Clark II & Rifkin, 2006). Domestic renewable generation technologies such as solar panels will become allied to electrolyser technology; hydrogen, transported in natural gas grids becomes available on demand universally. FCEVs provide cheap mobility and reduced energy bills allow for greater leisure time. In time as fuel becomes abundant, resource war becomes obsolete, and the Middle East becomes a peaceful and democratic region. In the words of Jeremy Rifkin (2003) the hydrogen economy delivers no less than the ‘re-distribution of power on Earth’, democratising access to energy resources. While the phrase ‘too cheap to meter’ is studiously avoided, the implication is never far away.

While this literature is at the more utopian end of discourse relating to HFCs, and has been robustly critiqued (Romm, 2005; Bossel, 2006), the promises of such visions permeate academic discourse relating to HFCs. Some form of hydrogen economy remains the desired (or at least a desirable) destination. However unlike the more utopian literature which tends to emphasise the inevitability

of ubiquitous hydrogen economies, the literature on HFC economics and engineering challenges tends to emphasise the multiplicity and contingency of potential HFC futures. In terms of cost; fuel cell mCHP requires order of magnitude cost reductions to compete with conventional boilers for domestic heating (Staffel & Green, 2009). FCEV costs, though seldom published by major manufacturers are thought to be greatly in excess of those for conventional automobiles (Bakkera, et al., 2012). While early models will likely be sold at a loss, mainstream manufacturers do not expect FCEVs to be competitive on a total cost of ownership basis until 2028, and initial purchase prices are still expected to be higher than diesel vehicles in 2030 (UKHM, 2013a, p. 10).

Moreover HFC face a number of infrastructural issues. Roll-out of smart metering and advanced grid technologies to integrate and manage fuel cell mCHP and electrolytic load balancing into UK energy grids remains patchy at best (Lund, et al., 2012; ITM Power, 2014). Finding incentives for the development of a national hydrogen refuelling infrastructure prior to the existence of a market for H₂ fuel is thought likely to prove challenging, as are surrounding issues of planning and health and safety regulation for H₂ which is currently regulated as a highly combustible industrial gas rather than a fuel (Romm, 2005; Ricci, et al., 2010). Across a range of HFC technologies, reliability and durability remain active areas for research and development and are expected to be so for some time to come.

What we see emerging across the HFC literature is contradiction between discourses favouring the environment on the one hand and economic efficiency on the other. The outcome of this disjuncture is far from clear. Emerging from the literature discussing challenges faced by HFC technologies is a generalised uncertainty regarding what the future may hold, an uncertainty that economic and environmental modelling and expert forecasts can only remedy up to a point. As Eakins & Hughes (2009) discuss, forecasting potential HFC energy systems is a somewhat fraught process. Modellers

have to contend with uncertainty over the pace of future technological developments, not only in HFCs but a range of competing technologies such as internal combustion engines; heat pumps and ultra-efficient boilers; batteries and flywheel energy storage. Similarly uncertainty over the feasibility of potentially allied technologies such as carbon capture and storage¹ (CCS), novel forms of hydrogen production and storage all have bearings on the output of the models used. Finally uncertainty over the levels of policy support for HFCs, future hydrocarbon prices and potential carbon taxes all have enormous impacts on what such models will select as cost optimal energy mixes in the period to 2050.

Partially as a result of such uncertainties proponents and scholars of HFC technologies have increasingly looked to theories of innovation and socio-technical transitions, either to guide policy recommendations for encouraging innovation or analyse the prospects for their success. Some commentators point to niche markets where the unique benefits of fuel cells (reliability, off-grid potential, quiet running etc) have a distinct commercial advantage over rival technologies. Often drawing on science, technology and innovation studies (see Chapter 3, p.38), these authors suggest niche applications and demonstration projects could provide early test beds from which technological advances, prototypic infrastructure and economies of scale may develop, in the same way the mobile phone batteries transformed the prospects for battery electric vehicles over the past decade (Agnolucci & McDowall, 2007; Eames & McDowall, 2010; Ekins, 2010b; Ekins & Hughes, 2010a; Hardman, et al., 2013). The degree to which this model can lead to a future where hydrogen can make a substantial contribution to reducing carbon emissions remains unclear however. HFCs are competing with multiple alternate low-carbon energy technologies, including renewable powered battery electric vehicles and heating technologies. The sums involved in HFC research,

¹ CCS in this context involves the production of electricity or hydrogen at centralised locations, where carbon emissions can be captured and stored underground in depleted oil wells or salt caves.

development & demonstration (RD&D) are significant, and the prospect of mass market production and infrastructure development are even more daunting. Put simply it is thought unlikely that private capital will be prepared to undertake such risks without the existence of;

- strong signals from government that energy security and decarbonisation will remain significant policy objectives;
- strong national guiding visions for HFCs role within broader energy and transport systems; financial support for breakthrough and early market RD&D activities, and;
- undertakings to provide sympathetic regulatory and market environment for the introduction of HFC (Ekins & Hughes, 2010b; Waegel, et al., 2006).

In their widely cited meta-analysis of modelling, visions and roadmaps for HFC technologies, McDowall and Eames (2006, p. 1248) note:

‘In ‘business as usual’ scenarios, hydrogen emerges slowly or not at all. In this literature, hydrogen only emerges quickly where governments take strong action in the face of climate change or security fears, or radical technological or social change occur.’

The purpose of this thesis will thus be to examine the ongoing processes through which governments have come to apprehend HFC technologies and the community emerging to seek policy support.

V. HFCs as Objects of Governance

Given the technological characteristics of HFCs, they have begun to appear in the discourse of both the UK and European Union as potential means of reducing carbon emissions and aiding the introduction of renewables in a number of sectors (CCC, 2010; DTI, 2004; European Commission, 2007). This is not to say HFCs have been accorded a similar prominence to offshore wind, nuclear, or even battery electric vehicles in contemporary policy discourse, rather they have been identified as a prospect worthy of accelerated innovation. During the early part of the 2000s strategic reports commissioned by the EU and UK government identified a range of policy priorities that could be met

through public policy support for HFC technologies, including decarbonisation and energy security objectives, as well as broader economic goals associated with global leadership in emergent low carbon technology and manufacturing (E4Tech Energy, et al., 2004; High Level Group, 2003). Seeking to identify not only the potential contributions of the technology, but also the barriers it faces in realising economic, environmental and security ambitions; this work has tended to situate HFCs within the realm of technological innovation. Within such work, the task of governance bodies is constructed as supporting the process of technological development and cost reduction to a point at which HFCs are ready for deployment at an economically competitive rate.

As an object of innovation policy, HFC technologies are part of a broader shift towards innovation in energy and business policy agendas. In their joint introduction to the UK Low Carbon Transmission Plan, Prime Minister David Cameron and his Deputy Nick Clegg announced:

‘In the 2020s, we will run a technology race, with the least-cost technologies winning the largest market share. Before then, our aim is to help a range of technologies bring down their costs so they are ready to compete when the starting gun is fired.’ (HM Government, 2011, p. 1)

To this end, successive governments have embarked upon a range of policy initiatives aimed at accelerating low carbon innovation. In 2009 the then Labour government launched the UK’s first Low Carbon Industrial Strategy. During the recession the UK was experiencing in 2011, the Conservative-Liberal Democrat Coalition government followed this up with its Research and Innovation Strategy for Growth, which likewise gave high emphasis to low carbon innovation as a policy priority (BIS & DECC, 2009; BIS, 2011). In a study covering the development of UK energy Innovation since the 1990s Winskel et al. (2014), describe a process of reform during the early 2000s during which interest in energy innovation began to grow, to a period of momentum building in the middle of the decade, accelerating to a greater sense of urgency in the period from 2010-2013. During this period a range

of bodies have been established, with both explicit environmental remits and remits focussed on economic growth. Table 2 (below) provides an overview of the key bodies and remits involved:

Table 2: UK Innovation System Bodies with an interest in HFC technologies

Organisation	Stated mission/role	Priority technology areas	Nature and scale of innovation
Research Councils' UK Energy Programme (mainly the EPSRC)	To position the UK to meet its policy targets and goals through high quality research and postgraduate training.	'Growing' research areas include energy efficiency, energy storage, whole systems including HFCs	Research grants to UK universities, and eligible research institutions. £110mp.a.(2011–12)
Technology Strategy Board	To stimulate technology-enabled innovation in the areas which offer the greatest scope for UK growth and productivity.	Fuel cells & hydrogen; offshore renewables; grid & digital energy; built environment: low impact buildings; transport; materials	Funding for RD&D projects, to multiple partners, up to £35mp.a. (2012–13)
Carbon Trust	To tackle climate change by creating a vibrant low carbon economy that delivers jobs and wealth.	Offshore renewables, biofuels and fuel cells	£10mp.a.(2010–13)from DECC; support for low carbon entrepreneurs

Source: adapted from Winskel et. al., (2014, p. 596)

Parallel to these developments, in the wake of long term decline in the UK automotive industry during the 1980s and 1990s, numerous Automotive Innovation and Growth Teams were established in the 2000s to inform future government innovation and skills policy, and encourage low-carbon automotive innovation as a means to restore the industry's fortunes (NAIGT, 2009; HM Government and Automotive Council UK, 2013). Since 2009, this coalition of civil servants and automotive industry experts has been institutionalised as the Automotive Council UK; a public private partnership bringing together the UK's major automotive manufacturers and supply chain companies with civil servants from BIS, DECC and DfT. The Council's Future Technologies Roadmap has identified range of strategic technologies in need of support with electric vehicles first to market to be followed by HFC vehicles from 2020 (HM Government and Automotive Council UK, 2013, p. 24). Responsibility for delivering this programme has at the state level been passed to the Office for Low Emission

Vehicles; a cross-Whitehall body with responsibility for managing up to £900m to boost the development and uptake of ultra-low emission vehicles (ULEVs) in the period to 2020.

At the EU level, HFC innovation has been effectively mapped onto the 2000 European Council Resolution for Jobs and Growth (the so-called Lisbon Strategy), and its successor Europe 2020 (European Council, 2000; High Level Group, 2004; European Commission, 2013). The broad thrust of such strategies is the transformation of the EU into an internationally competitive knowledge-based economy. Following the report of the EU's High Level Group for HFCs in 2003, HFCs were included as one of six Joint Technology Platforms under the EU's Strategic Energy Technologies Programme (Cavallo, 2007; European Commission, 2006; Soete, 2008). Rebranded in 2008 as the Fuel Cells and Hydrogen Joint Undertaking (FCHJU), this Platform has taken on the form of a public-private partnership between the EU, and the European HFC industry and research community. Operating across the full spectrum of HFC technologies the FCHJU was granted a budget of €450m by the European Commission for the period from 2008-2013 (FCHJU, 2011). Thus far UK companies and research institutions have received €71.05m (approx. £56m) from FCHJU (FCHJU, 2014, pp. 17-18), making it largest single contributor to HFC RD&D in the UK. While the FCHJU's remit is remarkably wide in terms of HFC technologies and applications, it is worth noting that as with UK policy it has been primarily aimed at transport and stationary applications. Over two thirds of its original five year budget was allocated to RD&D projects in these areas. A further 10-12% was allocated to hydrogen production and refuelling which covers some grid balancing type applications. It should be noted however that in some cases grid relevant applications such as hydrogen electrolysis for transport refuelling or exporting excess fuel cell mCHP generation to the grid, can be covered by projects funded under stationary or transport headings.

Insofar as innovation represents a policy area distinct from energy and transport, HFCs have been supported at various levels in the UK. At the academic level, the period from 2007-2018 has seen over £34m allocated to HFCs by the Engineering and Physical Sciences Research Council (EPSRC), including £5.5m for a five year Doctoral Training Centre based between the Universities of Birmingham, Loughborough and Nottingham; and £7.7m on its Supergen fuel cell research network and associated Hub based at Imperial College. At present HFC spending constitutes approximately 5.3% of all spending within EPSRCs energy programme (Dutton, et al., 2013, pp. 7-8; EPSRC, 2014a). Given the EPSRCs continued funding for the technology via open competitions, and the possibility of further investments in the future, this figure is likely to grow.

At the more applied end of the innovation spectrum, the Technology Strategy Board (TSB) allocated £7.5m to private sector development of the technology in 2012, and a further £19m has been committed from 2013 (Brandon, 2013, p. 14; Dutton, et al., 2013, p. 20). Primarily aimed at businesses these funds have been allocated to a range of demonstration projects and activities geared towards the development of new manufacturing systems and supply chains. In the early part of the 2000s the Carbon Trust ran a number of competitions for fuel cell mCHP technologies, notably taking a £1m equity stake in Ceres Power in 2003 (Carbon Trust, n.d.). In 2009 the Carbon Trust ran the DECC funded PEM Fuel Cells Challenge, a £10m programme aiming to bridge the gap between current PEMFC technology and the cost and durability requirements of mass market applications, particularly in transport (Carbon Trust, 2012). The ultimate beneficiaries of this project were three small to medium sized enterprises and two university research centres specialising in next generation PEMFCs and components. Since 2006 limited funding has been available for FCEV demonstrations through the DTI and one of its successor departments DECC, with £25.9m awarded to date (Dutton, et al., 2013, p. 26).

In addition to the innovation funding available, HFCs are making their way up the policy agenda. Support from bodies such as the EPSRC, Carbon Trust and TSB has been on an upward trajectory since the early 2000s, and is now being coordinated across government by the Low Carbon Innovation Coordination Group (LCICG) which, at the time of writing is in the process of drafting a Technology and Innovation Needs Assessment for HFCs. Public-private partnerships and academic-industrial research hubs have emerged in Aberdeen, Birmingham, London and Teeside; tasked with accelerating the introduction of HFCs for decarbonisation and economic growth (Hodson & Marvin, 2005; Hydrogen London, 2012; Stockford, et al., 2013). Fuel cell systems have been investigated by the All-Party Parliamentary Renewable and Sustainable Energy Group; the Climate Change Select Committee, and have been explicitly funded and researched by DECC; BIS and DfT. In 2012 former Business Minister Mark Prisk announced the formation of UK H₂ Mobility; a public private partnership between automotive and fuel cell producers and a range of infrastructure providers with the stated aim of '[making] hydrogen transport in the UK a reality' (UKHM, 2012; PRASEG, 2013; Energy and Climate Change Select Committee, 2010). At the European Level, the FCHJU is increasingly active in promoting coordination between private sector organisations; academic researchers and the EU, as well as promoting HFC technologies in broader European policy discourse (FCHJU, 2014). What we see emerging in the policy and academic literature surrounding HFCs is a gradual tightening of focus around a shared set of purposes, linked to the imperatives of energy security, emissions reduction and economic competitiveness.

VI. Summary

While the emergence of energy security and decarbonisation imperatives, and newfound enthusiasm for state promoted innovation will be discussed in the next chapter, discussion here has sought to situate HFCs within their present technological and policy contexts. As artefacts, HFCs have a number of characteristics which have allowed them to be situated in current energy and innovation policy debates. As artefacts for energy generation fuel cells are highly flexible and can be deployed in

homes and vehicles to generate energy far more efficiently than conventional locomotive, electricity and heat generating technologies. Even in the absence of large scale H₂ production and distribution infrastructures, the efficiency of fossil fuel powered FCs (particularly in domestic applications where heat and power are both required) means fuel cell mCHP could make significant contributions in reducing emissions from household energy demand over the medium term. When combusted or electrochemically reacted in an FC, H₂ produces no CO₂ emissions, holding out the prospect for decarbonising energy use in transport and domestic energy usage. When produced using fossil fuels H₂ production still produces lower emissions than contemporary combustion of these fuels. If powered using intermittent renewables, electrolytic hydrogen production produces no CO₂ emissions whatsoever, holding out the prospect of an entirely decarbonised energy and transport system. By acting as a buffer to absorb excess generation when wind and solar generation outstrip demand, H₂ production carries the added potential to increase the amount of intermittent renewable generating capacity that can be placed on the electricity grid. This excess H₂ could subsequently be used as a vector to move energy from electricity to transport applications, or alternatively be re-deployed in gas turbines or modified natural gas networks to support peak time electricity and domestic heating demand.

Given the globalised nature of decarbonisation imperatives, interest in HFCs derives not only from energy policy debates. As an emergent technology in a highly salient field they have also been taken as artefacts for economic growth. The UK's TSB; EU's FCHJU and regional public-private partnerships have recognised this potential and been supporting HFC innovation as part of broader industrial strategies for high-tech manufacturing. Often working in tandem with environmentally oriented public bodies such as the Carbon Trust, or in projects co-funded with DECC, these bodies form key focal points for HFC innovation in the UK. This is not to say the bodies themselves are engaged in HFC

innovation, rather they are funders of private sector and academic networks who comprise the ultimate deliverers of HFC artefacts and knowledge.

Nevertheless, despite their promise and growing levels of support under the UK's energy innovation system, the prospects for HFC innovation are uncertain. HFCs are granted a low profile in national policy discourse more often than not listed as a 'potential' rather than a target to be reached. Much of the literature regarding HFC futures thus remains uncertain as to the prospects for HFCs over the long term. While this work has tended to focus on the economic prospects for HFCs under a variety of energy system conditions, a gap emerges in relation to the policy process itself. Several studies have cited long term, stable policy commitments towards decarbonisation; clear visions and financial support for HFC development; and the establishment of sympathetic regulatory and market environments for the technology. However, there is an absence of research into how such commitments and developments are being established in practice. More specifically, we may ask how emergent networks of government departments; public bodies; and the various coalitions of academic researchers and private companies with whom they work, contribute to the process of managing HFC innovation and shaping the emergence of sympathetic regulatory futures? How is this community best conceptualised, and how is it integrated into established energy innovation systems? Given these questions remain unanswered, a case study of the HFC innovation community may offer valuable insights both for the prospects of HFC technologies; and help to shed light on if and how the UK, and to a lesser extent European innovation systems are functioning in promoting HFC technologies.

3. MAKING SENSE OF THE HFC COMMUNITY: SCIENCE, TECHNOLOGY AND INNOVATION STUDIES AND CONSTRUCTIVIST APPROACHES TO PUBLIC POLICY

I. Policy Studies and Science Technology and Innovation Studies

Literatures in two disciplines stand out as clear candidates for helping us make sense of the community emerging around HFC innovation governance; policy studies and science, technology and innovation studies (STIS). Within policy studies, there has since the 1990s been a large literature developing around the notion of policy networks and communities dealing with their effects on the state and policy processes (Rhodes & Marsh, 1992); their role in fostering expert learning and democratic deliberation (Hajer & Wagenaar, 2003); as well as their potential for reproducing existing interests and inequalities in power between different participating groups (Eagleton-Price, 2014; Sørensen & Torfing, 2005). More broadly, constructivist approaches to policy analysis have taken a particular interest in the role of ideas in enabling and constraining actor strategies in relation to broader policy processes and networks (Hay, 2007; Saurugger, 2013). Work in STIS, conversely has tended to focus at a more systemic level looking to broader sociotechnical transitions involving the transformation of large scale systems of technology, infrastructures and associated regulatory systems and practices (Rip & Kemp, 1998; Schot & Geels, 2008). Despite their distinct focal points, these literatures intersect at the point where large scale systems meet policy, that is to say where networks of technology producers; infrastructure providers; regulators and government funding agencies come together (Kern & Howlett, 2009; Scrase & MacKerron, 2009; Smith, et al., 2010). This holds both in studies exploring the maintenance of established institutions and regulatory regimes, and more importantly for the HFC community, for newly emerging policy networks looking to gain access to them.

In order to develop a conceptual framework through which we might begin to make sense of the HFC community, the following chapter provides an overview of three literatures, seeking to draw out the concepts most relevant to a study focusing on actors and innovation governance networks. Beginning by providing a brief overview of rational choice and historical approaches to the study of policy and STIS, the chapter problematizes straight-forward rationalist approaches for their relative failure to incorporate traditions, norms and ideas into their accounts of rational action within organisations and institutions. The chapter then shifts to examine social constructivist approaches to STIS (Geels, 2002; Rip & Kemp, 1998), notably transitions theory and constructivist policy analysis (Hay, 2007; Saurugger, 2013) as providing a range of concepts and models better suited to understanding contemporary processes of innovation governance. In particular it highlights transitions theory's focus on learning in niche-regime innovation networks and constructivist accounts of the interrelation between ideas, institutions and strategic action as key points of orientation for a study looking to HFC innovation governance.

While not proposing a synthesis between these two distinct traditions, the final section of the chapter focus on the point at which STIS and policy analysis have most often met; in accounts of the policy paradigms and interests in UK energy and innovation policy, and studies of the Dutch experience of purposive transitions management during the 2000s. In so doing the chapter notes a continuing tension between accounts of transitions processes as relatively open deliberative fora, and those focussing upon the role of positional power and interest in shaping the institutional frameworks in which innovation policy deliberation and learning are emerging.

Rational Choice and its Critics

To begin, much of the current debate in writings on HFC innovation begin from a broadly rational choice view point. Rational choice theory is predicated on the methodological individualist notion

that the primary unit of social organisation is the individual, an autonomous agent whose actions are guided by rational, consequentialist calculation. By consequentialist, rational choice theorists refer to decision making that considers the range of alternatives available to an actor, in light of contextual constraints, and in anticipation of the outcomes of each alternative (Elster, 1986). Within this model calculation is geared towards maximising or, under conditions of uncertainty 'satisficing' the interests of the actor (March, 1986; Simon, 1972). Interests in this view tend to be seen as products of cost benefit calculations in which material benefit tends to be the primary criterion (Dowding, 2008; Elster, 1986), although alternate models have been suggested for incorporating ideas, values and beliefs into this framework (Boudon, 2003). Despite their methodological individualism, rational choice approaches argue that in so far as collective action provides the most rational path to securing individual interests, rational agents can and often do submit to collective organisational and institutional rule structures and goal sets. To the extent that they mobilise larger numbers of rational agents, each possessing the power and resources to execute particular tasks and work collectively towards collectively agreed and predetermined goals, organisations and institutions can thus be seen to act as rational agents in their own right (Dowding, 2008; March, 1986). The key insight rational choice approaches claim is thus the positivistic insistence that provided with knowledge of the position of actors involved in a given activity, and the strategic context or 'the rules of the game' in which they meet, we can model and predict the outcomes of economic, political and sociological interactions.

In this view HFC innovation is best understood in terms of cost optimisation. Rational choice models of technological innovation and systems change find a voice in economic models of technological innovation and change which assume that governments; businesses and citizens will opt for least cost technologies to reach their desired ends, be these maintenance of business as usual scenarios or transitions towards low carbon hydrogen energy systems (Dodds & McDowall, 2013; Balta-Ozkan &

Strachan, 2010). In this view the existence or anticipation of decarbonisation or cost minimisation represent 'market pull' factors which incentivise firms to generate technological solutions that can then be pushed to market for profit. Similarly governments simply need to incentivise technology push activities to obtain or accelerate the realisation of desired policy goals (Chidamber & Kon, 1994).

STIS emerged in part out of dissatisfaction with 'technology push' and 'market pull' models. Pointing to numerous case studies from laboratory experiments to the invention of Bakerlite and the two wheeled bicycle, such studies argued that far from the result of rationally calculated decisions, innovation is the product of the infrastructures; ideologies; fashions and norms of the cultures in which they are produced (Bijker, et al., 1987; Bijker, 1997). Similar sentiments can be found in the foundations of actor-network theory, which holds that scientific and technical systems are dependent on the construction and maintenance of stable frames of meaning which allow scientists; research funders and technology users to make sense of techno-scientific issues and develop common approaches to their resolution (Callon, 1986; Latour, 1988; Law & Singleton, 2014). While these literatures carry distinct differences, particularly in their accounts of agency in relations between actors and other artefacts (for a discussion see; Law, 1999); for the purposes of discussion here they all fall within a broadly constructivist interpretive framework. This is to say they view technological innovation as not merely influenced but shaped by broader intersubjectively produced meanings and infrastructures.

In policy studies rationalist assumptions are visible in literatures on pluralism and elitism which contend political institutions and networks represent either mechanism for the control and dispersion of power between competing pluralist interests (Dahl, 1961; Polsby, 1960), or as resources

for the maintenance and transmission of elite power and control of decision making options and processes (Bachrach & Baratz, 1962; Mills, 1959). Similarly corporatist theory of the 1970s and 1980s focussed on the institutionalised representation of capital and labour interests as a means of explaining legalistic and technocratic process of industrial policy decision making (Schmitter, 1974; Panitch, 1980).

However rational choice and related approaches have been critiqued from a range of approaches. Historical institutionalists contend that institutional context is a central feature of processes of interest, goal and preference formation that tend to be bracketed out or assumed in rational choice accounts (Thelen & Steinmo, 1997). In this account the behaviour of individuals and organisations cannot simply be understood through reference to the present strategic situation, rather they depend upon historically contingent processes of institutional development whose explanation requires historical analysis; 'Once a particular fork is chosen, it is very difficult to get back on a rejected path' (Krasner, 1984, p. 225). Central to the difficulty of altering paths once one has been selected is the notion that institutional processes often include processes of increasing returns, whereby institutional designs and practices become self-reinforcing, limiting the range of choices available to otherwise rational actors. Pierson (2000) identifies two particular forms of increasing returns; in the first the development of regulatory systems, infrastructure and staffing around a particular policy choice mean the costs of switching policy increase markedly over time. In the second the order and pacing of institutional developments mean once an initial decision is taken, wider ranges of social systems and regulatory infrastructures gradually become co-dependent upon it; making the initial choice far more difficult to change without disrupting these other systems. For instance Walker (2000) demonstrates how the selection of a particular form of nuclear reprocessing technology for the UK institutionalised a plethora of economic, organisational, legal, social and political commitments on the part of technology producers, regulators and policy makers which grew

exponentially since the initial technology choice was made. Inertia between these processes, combined with the costs of switching to emergent alternatives have subsequently hindered the adoption of what are generally agreed to be superior alternatives in terms of cost, efficiency and safety.

Furthermore research into sociological institutionalism in the 1970s and the 'new institutionalism' of the 1990s point to a range of informal institutions; culturally transmitted social norms; rituals and obligations which operate to undercut rational calculation and influence the rules of formal institutions and organisations (Meyer & Rowan, 1977). As organisations expand to incorporate new fields of expertise or activity, they draw on deeply embedded traditions; rituals and myths as heuristics for making sense of their new roles and determine the appropriate norms, rules and structures for the task at hand (Dowling & Pfeffer, 1975; Meyer & Rowan, 1977). It is in this sense that DiMaggio and Powell (1983) argue that over time and under prevailing conditions of uncertainty, organisations undergo a process of isomorphism. Such isomorphism can be structural with regulatory structures and professional codes embedding particular institutional forms as the only legitimate form recognised by regulators and professionals, or spread through a process of mimesis with particular norms and institutional rules spreading as staff from one organisation migrate to others (DiMaggio & Powell, 1983; Peters, 1999). Through this process, 'proven' organisational structures and practices come to be seen as legitimate and effective by virtue of the traditions and rituals they have developed. It is in this sense March and Olsen (1989, pp. 23-24, 160-162; 2004) claim individuals in an organisation tend to conform to logics of consequentialism and appropriateness. While the former covers the capacity for organisational actors to make rational judgements with regard to a particular action; the latter reflect the constraints that broader values, traditions and norms of action place on such judgements.

Given the above, it would appear that as a framework for considering the community engaged in HFC innovation governance, rational choice approaches carry some limits. Firstly, in identifying a range of sociocultural factors in the development of new technologies, sociological and new institutionalist perspectives in STIS and policy studies raise fundamental questions as to whether members of the HFC community can be considered solely motivated by interests derived from their position in existing energy regimes. Secondly, in light of issues of structural isomorphism and technology lock-in, additional questions remain as to if and how HFC proponents are gaining access to what is a highly mature and embedded system for energy innovation. While the answers to these questions may partly be located in strategic rational action, they none-the-less seem to demand an additional conceptual framework rational choice approaches do not provide. As such, the following two sections outline two distinct approaches to the study of innovation governance; socio-technical transitions theory and constructivist policy analysis.

II. Transitions Theory

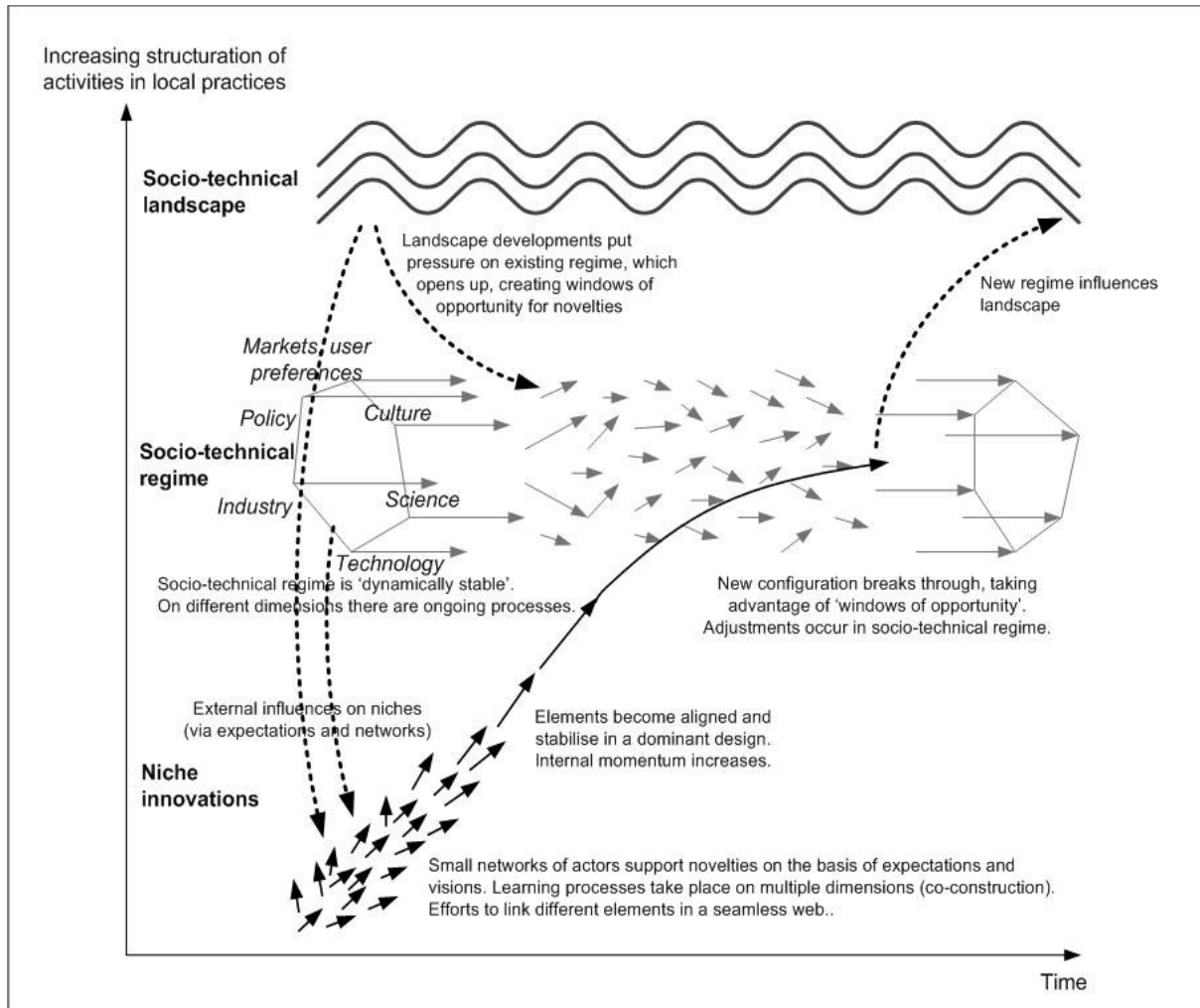
Located at the intersection between constructivist approaches to science and technology studies and sociologically informed evolutionary economic studies, transitions approaches to STIS take innovation to be a systemic process. In the first instance, transitions theorists accept historic processes of path dependency and established infrastructural, regulatory and ideational systems can produce technological 'lock in' (Bolton & Foxon, 2015; Walker, 2000). This is to say once a given socio-technical system has been established, systems of technology production, regulation and innovation tend to co-evolve with user practices, norms and values producing a highly exclusionary environment for emergent technologies that do not neatly conform to the established framework (Rip & Kemp, 1998; Geels, 2010). This is not to say radical disruptions do not occur. Just as processes of increasing returns and regulatory co-evolution can lock-in and protect incumbent firms and technologies; these same processes can also inhibit them from adjusting as new markets, regulatory systems and user practices emerge (Christensen, 1997; Hardman, et al., 2013).

Particularly prominent in this literature is Rip and Kemp's (1998) account of technological change, in which they argue that historically, technological innovations have emerged in small applications and market niches, protected from the full force of competition with incumbent technologies. Within such niches, protection can be offered by a number of factors; an innovation may offer specific functional or performance benefits in a particular professional community or small industry sector. Similarly government subsidised RD&D programmes; university laboratories and corporate R&D centres offer spaces specifically designed to allow new technologies to flourish (Rip & Kemp, 1998; Rotmans, et al., 2001; Loorbach & Rotmans, 2006). The central point within such accounts is that niche protection provides spaces for experimentation and technological learning that are unavailable in wider technology markets. In this literature strategic niche management becomes a means for policy makers to consider creating spaces for emerging low carbon innovations by providing localised and temporary support mechanisms for RD&D and aligning policy discourse and market regulations to send a clear message about the type of innovations desired (Hoogma, et al., 2002; Schot & Geels, 2008).

Expanding on Rip & Kemp's work, the multi-layered perspective put forward by Frank Geels (2002) and others, positions niches within a 'nested hierarchy' (see figure 2), subordinated to sociotechnical regimes and landscapes. Here the regime comprises a patchwork of existing infrastructural configurations; technologies; policies; regulatory norms and user practices which allow existing sociotechnical systems to function. Thus the regime for electricity presently comprises extractive industries; electricity generation; supply and retail companies; the regulator Ofgem; as well as the patchwork of primary legislation and regulatory decisions that structure existing energy markets. Allied to this the regime are civil servants and policy makers in DECC who are ultimately responsible for the smooth running of the system as a whole; as well as a whole gamut of regulatory norms and

consumer practices ranging from competition rules and safety standards to procedures for billing and taking meter readings.

Figure 2: The MLP



Source: Geels (2002, p. 1261)

The embedded nature of these systems is what makes the maintenance of the regime possible, but their widespread nature also has the effect of narrowing and reinforcing the selection criteria for innovation and regime evolution. Thus while changes in public practices and disruptions such as threatened boycotts or the adoption of new technologies may undermine existing regimes, expectations over the continuation of dominant or entrenched practices can likewise restrict what is thinkable in terms of regime innovation (Schot & Geels, 2008; Smith, et al., 2005). It is this entire system which underpins the functioning of the dominant set of fossil fuel and nuclear driven

electricity generation technologies in the UK, and this exists in partial overlap with a range of other regimes for transport; industrial manufacturing; finance etc.

Conversely, the landscape comprises long term change processes that are relatively stable and slow moving such as the climate; geology and resource levels, rapid shocks from outside the regime such as war and resource price spikes, and long term trends such as demographic change; globalisation and increasing international trade (Geels, 2002; Van Driel & Schot, 2005). Within this hierarchy, higher layers operate to structure those beneath them. Landscape developments shape the development of regimes, and regimes both purposefully and inadvertently shape niches, however the process is never fully determined. Rather, sheltered space provided by niches can provide the opportunities for innovative technologies and practices to emerge, actors within the m forging relationships with regime actors leading to gradually upscaling and regime transformation. Similarly long term developments within and across multiple regimes can effect landscape developments such as climactic change over the longer term.

In considering this trifold distinction, niche management and transitions based approaches argue that despite the structure and inertia built into any long standing socio-technical regime, this level is open to purposive attempts at transformation through collaborative processes of deliberation, learning and strategic niche management (Kemp, et al., 2007; Schot & Geels, 2008). Thus transitions scholars interested in shifts towards more sustainable socio-technical systems have sought to provide guidance on how regime evolution can be steered towards greater levels of low-carbon innovation and policy adaptation (Meadowcroft, 2005; Rotmans, et al., 2001). This is not to say transitions approaches seek to advance the cause of particular low carbon technologies.

Collaborative approaches to regime transformation are necessarily socially contingent and difficult to

predict in advance (Rotmans, et al., 2001). Within such approaches the task of managing transitions thus becomes one of maintaining an open and supporting environment for new innovations to emerge in the niche, and where possible avoiding developments at the regime level that may lead to the 'lock-in' of existing high carbon technologies. Predicated on accounts in evolutionary economics which seek to combine rational choice frameworks with insights from sociology and constructionism; advocates of the multi-layered perspective and similar approaches argue that the expectations of rational investors and businesses can be shaped by long term policy commitments to sustainability goals, and the creation of networks to facilitate contact; co-ordination and learning between researchers; niche technology innovators and incumbent industries and policy institutions (Ekins, 2010b; Foxon & Pearson, 2008; Loorbach & Rotmans, 2006; Schot & Geels, 2008). While different writers adopt differing terminology and at times include additional factors, we can distinguish five broad principals to such a regime:

1. Long term frameworks for technological development, linked to sustainability goals;
2. The active promotion of protected niches for a variety of technologies from near to market to longer term prospects;
3. A public-private institutional structure designed to keep government aware of innovation requirements and ensuring participation of all actors in the innovation community;
4. Integration of innovation and energy policy processes and instruments, rooted in principals of carbon reduction and openness to new technologies.
5. Policy learning facilitated by regular coordination between innovation system actors, evaluation and reviews of progress in specific technology areas.

In the case of HFCs multiple attempts have been made to make sense of innovation challenges in relation to this framework. In a comparison between HFC vehicles and past transitions to seven other disruptive technologies Hardman et al. (2013) found the technology currently lacking in niche market

applications where it offers significant prestige or use value coveted by end users. Other studies have simply deployed transitions perspectives as a means of considering the challenges faced by HFCs and providing policy recommendations to support them (Agnolucci & McDowall, 2007; Ekins & Hughes, 2010a), or as a model for developing scenarios and collective visions for the technology (Eames & McDowall, 2010; McDowall, 2012). To the degree that these activities contribute to the development of policy learning and long term visions for HFC technologies, they can themselves be read as part of a transitions management processes. However, no study to date has sought to conceptualise the UK HFC community in these terms. That is to say, thus far little work has been conducted to establish the degree to which niche HFC actors are becoming involved and integrated into the public-private institutional structures developing for energy innovation in the UK, nor whether such activities are likely to contribute to the development of long term frameworks for the technology. At the current time we still lack the knowledge as to whether the UK HFC community corresponds to the categories of innovation theory, or whether some alternative framework may be more appropriate. However insofar as HFCs currently represent a niche technology (costly, lacking in widespread use, but with potential to disrupt widespread systems and infrastructures in electricity, heat and transport), the initial categories of niche and regime provide a valuable conceptual starting point for considering interactions between the UK energy innovation system and proponents of the technology.

Critiques of Transitions Perspectives- a Need for Policy Analysis?

Useful though it may be transitions theory alone is insufficient as a mechanism for making sense of the HFC community in UK innovation governance. Indeed the approach has been critiqued from a number of perspectives for its lack of attention to agency (Genus & Coles, 2008; Smith, et al., 2005), and its failure to incorporate notions of power into its conceptual framework and policy programme (Shove & Walker, 2007; Smith, et al., 2010). Finally the concept of landscape has been critiqued as a residual category that is underspecified both in terms of what it contains and the mechanism through which it affects the regime and vice versa (Smith, et al., 2005). While the author has some

sympathy for these criticisms, it should be noted that in its more reflexive variants issues of power and agency have been addressed within transitions theory itself. On the subject of agency, Geels and others have emphasised on more than one occasion that at the level of niche innovation high levels of social agency exist in the development and adaptation of new technologies and practices (Geels, 2010; Schot & Geels, 2008). Rather proponents of transitions approaches would suggest that as we move up the Y axis shown in figure 2 (p.40); higher levels of structuration begin to have a greater impact on agency (Geels, 2011, p. 29). Given the critiques of rational choice approaches unencumbered account of agency, such a position has some merit.

On the issue of power and the mechanisms through which sociotechnical landscapes affect other levels, transitions theorists can and do point to the interdisciplinary nature of the approach itself and its capacity to draw on notions of agency; discourse; institutionalisation and structuration in order to explain and incorporate inequalities in power relations between niche and regime actors (Geels, 2011; Grin, 2010). It is in the spirit of such cross disciplinary insight that the following chapter turns to constructivist approaches to policy analysis. Sharing many of the ontological assumptions of transitions theory, this approach offers additional depth and insight on issues of agency and power which while covered within STIS, are not its main point of concern.

III. Constructivist Approaches to Public Policy Analysis

Constructivist approaches to policy studies begin from the shared assumption that ideas play a key role in the development and conduct of public policy. While the precise role accorded to ideas varies from the critical realist mantra; 'reasons can be causes' (Fairclough, et al., 2003, p. 2); to notions of policy paradigms (Hall, 1993; Wilder & Michael, 2014); institutionalised discourses and cognitive frames (Schmidt, 2008; Campbell, 1998); or the refinement of sociological concepts such as culture into learnt norms and collective problem framings (Börzel & Risse, 2003; Checkel, 1999),

constructivist approaches assume that we cannot understand social interaction without attending to the ideational. Within this approach there is some tension between what might be distinguished as 'strong' and 'weak' forms of constructivism, with stronger forms erring towards post-structuralist positions that problematize any concept of the material beyond human ideational and semiotic systems (Gottweis, 2003); and weaker forms that consider ideas as a framework through which material interests are understood (Adler, 1997). Notwithstanding these differences, all would agree that the traditional rational choice approach to interests as products of an actor's location in relation to their material context is to some degree flawed.

Given the plethora of monikers attributed to this literature and its overlaps with other positions with different, though overlapping, ontological assumptions, any attempt to summarise constructivism is likely to be met with some criticism. However, some means are required to draw out some of the key distinctions within constructivist policy literatures. For the purposes of discussion here Saurugger's (2013; see table 3, below) distinction between socialisation and learning, discursive institutionalist and actor centred constructivist approaches provides a useful structure for examining constructivist insights. While recognising such distinctions present some difficulties, particularly in conflating constructivist ontologies with similar but distinct post-structuralist approaches; Saurugger's approach has the benefit of clarity in identifying key aspects within constructivist writing of relevance to this study. In particular, this section identifies actor centred constructivism's orientation to the strategic use of ideas as of particular value in conceptualising the HFC community as an object of enquiry. Having done so, the chapter will then shift its attention to the literature emerging around energy policy paradigms as a key point of intersection between constructivist policy analysis and STIS.

Table 3: Approaches to Constructivist Public Policy

	Sociological Institutionalism	Socialisation and Learning	Discursive Institutionalism	Actor-Centred Constructivism
Elements Explaining Change	Informal institutions, identity, shared experiences, cognitive frameworks	Formal and informal institutions	Informal institutions, discourses and ideas	Formal and informal institutions, Rational calculation.
Subject of Analysis	Cultural standards and cognitive frameworks	Actors' attitudes in decision making processes	Ideas and discourses	Rational calculation framed by embeddedness in formal and informal institutions
Logic of Explanation	Logic of social Conventions	Socialization and learning	Communication	Strategic Calculation

Source: Saurugger (2013, p. 892)

Sociological Institutionalism, Socialisation and Learning

While not constructivist, in the sense that it does not explicitly locate concepts of culture, tradition or ritual at the ideational level, the sociological approaches to institutions discussed earlier (p.36-39) provide an insight into broader constructivist positions (Hay, 2007; Schmidt, 2008; Saurugger, 2013). Problematically however, sociological institutionalist categories remain somewhat underspecified and appear to exist at the same residual level of the landscape in transitions theory approaches. That is to say no mechanism is specified to explain why actors remain attached to them. Developed further in socialisation and learning based approaches to the policy process, culture takes the form of systems of normative ideas regarding appropriate and legitimate forms of behaviour and decision making. Here collective institutions for policy making represent embedded sources of ideas and dispositions which allow those within them to learn from past experience and shape the responses actors deem appropriate to policy work and emergent problems (Bennett & Howlett, 1992; March & Olsen, 2004). For proponents of these approaches, institutions and organisations provide the primary focal point for learning processes, enabling the development of shared understandings of complex

problems, and the development of mutually agreeable bargaining processes and solutions around them (Börzel & Risse, 2003; Checkel, 1999). In this way, transitions theory recommendations and energy policy approaches emphasising public private partnership become explicable in their attempts to make sense of common system problems and identify common interests amongst diverse actors (Rotmans, et al., 2001).

That being said, not all institutionalised bargaining processes are underpinned by common problem framings. In some such framings are only possible within relatively narrow technocratic communities, or through the denial of contingency and closing down of alternate framings (Saurugger, 2013; Wood, 2015). Thus in numerous studies of purposive transitions management policy approaches in the Netherlands, findings have noted a tendency for regime and niche based actors to approach the transitions process with very different visions as to the nature of the infrastructural changes required, with regime actor understandings generally prevailing (Hisschemöller & Bode, 2011; Lehtonen & Kern, 2009; Smith & Kern, 2009). While valuable in explicating instances of consensus policy making, socialisation and learning processes on their own seem insufficient to the task of examining cases of conflict in policy institutions and networks.

Discursive Institutionalism

Discursive institutionalist approaches conversely have taken language as their primary focus. Drawing on Hall's (1993) work on policy learning and paradigms, discursive institutionalist approaches begin from the argument that policy institutions and instruments reflect highly embedded systems of ideas regarding policy goals and the legitimate means of meeting them (Schmidt, 2008). Where discursive approaches expand on this concept is in attending to language and communication as the medium through which these ideas flow and become inscribed in policy institutions and instruments (Chouliaraki, 2008; Fairclough, 2003). In positioning social actors and institutions as mutually linked

through meaningful systems of language and communication, the concept of discourse operates to explain how actors come to understand the world around them and act upon it in a meaningful way (Hay, 2007). For Schmidt (2012, pp. 92-95), this process is attributable to two sets of abilities made possible by language; 'background ideational abilities' and 'foreground discursive abilities'. The former, represent our capacity to attach meaning and values to particular practices and goals, allowing for coordinated action and its embedding in institutional structures, rules and routines. 'Foreground discursive abilities' conversely reflect our capacity to consider and communicate; to bring together background skills from the multiplicity of institutional contexts in which we operate, in order to compare and evaluate their underlying ideas. It is this process that makes possible processes of policy change through the dissemination and legitimation of new ideas and policy practices.

While not featured within Saurugger's typology, we might include within discursive institutionalism deliberative approaches to policy studies, which also focus on communicative interaction and argumentation. Although much of this literature stands out due to its normative commitment to Habermasian notions of deliberative democracy, in attending to the nature and quality of communicative interaction, deliberative approaches likewise invoke ideas embedded in discourse as a means of examining policy institutions and networked governance processes (Hajer & Wagenaar, 2003; Dryzek, 2005). In particular deliberative approaches to STIS and ecological modernisation theory have focussed upon the nature and quality of policy discourse. Distinguishing between relatively open participatory approaches to communication and collaborative storyline development, and more closed off technocratic fora they argue the former have been far better at generating reflexive consideration of policy goals, whereas the latter have tended to result in a focus on technological fixes that fail to challenge contradictions and power imbalances that give rise to policy problems (Christoff, 1996; Hajer, 1996; Lehtonen & Kern, 2009). Of particular importance in this regard is the role of ideas and language as embedded in network activation or 'meta-governance'

strategies; the discourses state actors institutionalise within deliberative fora and policy networks when setting agendas and goals; allocating remits and specifying the actors whose participation should (and should not) be sought (Hudson, et al., 2007; Sørensen & Torfing, 2009; Swyngedouw, 2005). To the extent that deliberative approaches imply a process of dialogue; exchange of knowledge and learning, this concern means such approaches do not reside solely at the discursive level but cross into constructivist accounts of socialisation and learning. Previous studies of innovation governance operating in this tradition have thus sought to anchor their accounts of policy processes in terms of the deliberative and institutional spaces afforded to niche actors and their narratives (Hisschemöller & Bode, 2011; Lehtonen & Kern, 2009; Smith & Kern, 2009). However, discursive institutionalist accounts have often tended to leave open the question of where discourses come from, specifically whether they represent disembodied systems of meaning or, reflect some form of materially or ideationally grounded strategy or interest (Hay, 2004; Saurugger, 2013). It is on this question that Actor Centred Constructivist accounts focus.

Actor Centred Constructivism

Whereas other constructivist approaches have tended to focus on ideas as, to a degree, disembodied from interests and the material world; actor centred constructivist approaches turn to look to ideas as a source of strategic action (Saurugger, 2013). The notion that ideas can be strategic is not unique; it is present in many constructivist accounts and a range of cognate traditions in which ideas are conceptualised as a weapon in securing legitimacy for a particular course of action (Blythe, 1997; Jessop, 2010; Law & Singleton, 2014; Schmidt, 2008). In pointing to this process, Saurugger (2013) argues, as per earlier institutionalist accounts, that actors follow not only logics of appropriateness but also logics of consequence (March & Olsen, 1998). While logics of appropriateness may frame particular consequences as more or less legitimate (March & Olsen, 2004), actors may invoke particular ideas not only as valued expressions of identity or value but as part of a broader strategy to achieve a particular consequential outcome in which they are interested. Moreover in deploying

ideas instrumentally to frame or legitimise a policy issue in a particular way, actors can mobilise broader groups of actors in support of their interests (Surel, 2000). This is not to say actor centred constructivists view the notion of interests un-problematically as located in some notion of ‘real’ or ‘material’ interests, rather:

“public policy is understood as the result of the interaction between individuals whose interests are not only based on a rational cost–benefit calculation, but must be understood as something that is embedded in specific social representations, values and norms in which the actor evolves” (Saurugger, 2013, p. 900).

Thus for the actor centred constructivist, ideas are not determined by material interests, rather the two are co-dependent; ideas framing and legitimising interests, and being reproduced, challenged and transformed by them (Hay, 2007). The key concern of actor centred constructivism thus becomes, the process through which actors in a given policy situation come to interpret their interests within it and deploy ideas in order to realise them (Hay, 2011; Saurugger, 2013). Insofar as it points to complex, collective processes of institutionalised communication and bargaining, this approach inevitably overlaps with the concerns of deliberative and social learning approaches to constructivist policy studies. However the distinction here lies with the primacy actor centred constructivism gives to actor interpretations and constructions of ideas and interests.

It ought to be reiterated at this point that the typological distinctions made by Saurugger (2013) are by no means absolute. As the overlaps between categories suggest, many authors attributed to particular approaches may not subscribe entirely to the archetypes outlined above. This is particularly the case with actor centred constructivism which is a category of Saurugger’s making rather than a longer standing constructivist tradition. Nevertheless in outlining the field of constructivist approaches in this way this section has provided numerous points of orientation from which one may go about making sense of the HFC community within broader energy innovation systems. In particular it sensitises us to the HFC community as comprising a variety of actors who

may carry with them a broad range of ideas and interests, developed through a variety of ideational and normative experiences. Whether these actors are engaged in processes of socialisation and learning or strategic competition is less certain from the literature. While transitions theory appears to recommend the former in its references to policy learning and coordination between innovation system actors, it has not been adopted as official policy in the UK, although as we shall see below, there is limited evidence to suggest that if it has had an influence it has only done so selectively (Kern, 2012; Winskel, et al., 2014). Where there is more evidence to guide our understanding of what is going on in the HFC community, is in relation to notions of the policy ideas or paradigms guiding the broader development of the UK energy and innovation system, and of the processes by which previous expert and interest groups have been incorporated into policy processes. It is to these that the following sections turn.

IV. Policy Paradigms

In studies of shifts in UK energy and innovation policy towards models promoting innovation, several scholars have drawn upon Hall's (1993) notion of policy paradigms and subsequent constructivist modifications to it (Fudge, et al., 2011; Helm, 2007; Kern, et al., 2014; Mitchell, 2008). Before outlining these approaches, it is first worth pausing to consider his approach from a more explicitly constructivist perspective. Drawing on early, more rationalist approaches to socialisation and learning (Hecló, 1974; Sacks, 1980) Hall subdivides policy change into three distinct orders; calibration, instruments, and goals. First order changes are the most common, representing the day to day business of policy making, altering the calibration or the settings of policy instruments. Second order changes represent shifts in the policy instruments themselves. Based on dissatisfaction with past performance of instruments such changes reflect the introduction of new means to reach the same goals. Finally third order changes alter the goal structure for policy itself. As such while the first two orders of change reflect relatively endogenous processes of technocratic social learning within formal institutional structures; the later involves challenge to the very ideas that legitimise and

normalise decision making around a particular set of policy goals and instruments. For Hall (1993), third order changes thus reflect Kuhnian paradigm shifts where normal frameworks for understanding and acting break down; the point at which new ideas, from outside the institutionalised learning process make an entrance. Unlike Kuhn (1962), for whom such shifts reflect the build-up of empirical anomalies and the replacement of demonstrably flawed theory with an empirically superior alternatives, for Hall policy paradigm shifts are political constructs, adopted when politicians and administrators subscribing to a particular view point gain positions sufficient to implement their alternative visions. As such a policy paradigm constitutes:

‘a framework of ideas and standards that specifies not only the goals of policy and the kind of instruments that can be used to attain them, but also the very nature of the problems they are meant to be addressing.’ (Hall, 1993, p.297)

Developing the notion further, theorists operating in discursive institutionalist and actor centred constructivist approaches to policy studies have variously described these frameworks as ‘interpretive schemas’, ‘cognitive frames’, or ‘background ideational abilities’, which allow policy actors to make sense of the world and their actions (Hay, 2007; Schmidt, 2008). Often these frames remain unarticulated, operating on the basis of commonly held values and assumptions about the goals and means appropriate to the conduct of public policy; they function to enable and constrain particular forms of policy learning and practice. In this broader sense of the term, policy paradigms consist of coherent sets of ideational or ideological dispositions which establish those functions and goals deemed appropriate for institutions to pursue. The paradigm thus functions to shape the goals of policy, and in turn instruments, settings, and the broader institutional configurations in which they are based.

Thus in Hall’s (1993) classic example of the shift from Keynesian to Monetarist economic policy making in the UK, drastic alterations in the key instruments of macroeconomic policy making were prefigured by a series of economic crises in the 1970s which functioned to discredit ideas of the state

as an effective planner for economic growth; leading to an eventual shift in goals from the maintenance of full employment to the control of inflation. This change in goals corresponded to the emergence of a new discourse explaining the crisis in terms of overly powerful unions, and inefficiencies derived from state intervention in the market. Initially highly controversial, this discourse attracted support from powerful social groups in academia, the City, and prominent right wing think tanks, before entering Conservative Party and UK policy discourse (Desai, 1994; Hall, 1993; Harvey, 2006). The embedding of this discourse in new policy instruments; processes of institutional reform, and the interpretive schemas of policy makers and civil servants distinguishes this process as a paradigmatic shift. In this view paradigms operate to structure the interests and agency of actors, while at the same time, as per actor centred constructivist accounts; operating as strategies for divergent groups to challenge or legitimise particular framings and solutions to policy problems which coincide with their interests.

While the broad notion of policy paradigms has been widely adopted within constructivist and transitions literatures, a number of studies have emerged which depart from the above model to various extents. In particular, Hall's notion, derived from Kuhn (1962) that paradigms and their replacements must be incommensurable to one another, seems at odds with constructivism's emphasis on human capacities for creative language and communication in bridging between different institutionally mediated interests and contexts (Hay, 2007; Schmidt, 2008; 2012). Empirical re-analysis of Hall's work in UK economic policy, as well as examination of paradigmatic shifts in other policy domains have suggested high levels of overlap; synthesis or layering, in which advocates of new goals battle for their institutionalisation alongside pre-existing ideas and instruments (Kern & Howlett, 2009; Oliver & Pemberton, 2004; Wilder & Michael, 2014). In this view paradigmatic shifts take on a more gradualist character; capturing areas of policy making and establishing new formal

and informal institutions which may adapt or modify previous paradigmatic structures or coexist uneasily alongside them.

V. Paradigms and Ideas in UK Energy Policy

The concept of policy paradigms has been particularly influential in studies of shifts in energy and transport policy since 1979, and by extension state approaches to innovation in these fields. Several authors have attempted to trace how energy, and to a lesser degree transport policy have been effected first by a move towards market liberalisation, and more recently under environmental and security concerns. While some of this work is constructivist in nature, drawing attention to the role of ideas in generating policy outcomes (Fudge, et al., 2011; Kern, et al., 2014), others adopt more Kuhnian accounts which focus more on material anomalies giving rise to distinct eras in policy and institutional configurations (Helm, 2007; Pollitt, 2012). A considerable literature has emerged over the past decade over the prospects for a new paradigm in UK energy policy (Helm, 2005; Kern, et al., 2014; Mitchell, 2008). Drawing both explicitly and implicitly on the work of Kuhn and Hall, this work identifies three broad paradigms corresponding to distinct periods in UK energy policy post 1945 characterised by nationalisation; market liberalisation; and more recent challenges posed by climate change, energy security and affordability.

The nationalisation paradigm is generally dated between 1945-1979 and was shaped by the broadly Keynesian macroeconomic ideas governing UK economic policy at that time. Within this paradigm, state provision of secure and affordable energy was considered a prerequisite for overarching goals of economic growth and maintenance of full employment (Hall, 1993; Helm, 2005; Mitchell, 2008; Oliver & Pemberton, 2004). To this end a range of new policy instruments were developed, building on the nationalisations and centralised planning first introduced during the Second World War. Key tools included the nationalisation of electricity, coal and gas generation and transmission assets, and

centralised government planning of future infrastructure provision based on desired and predicted rates of economic growth. The unravelling of this paradigm came as part of the broader shift from Keynesian macro-economic management to monetarist and subsequently neoliberal forms of governance during the 1980s. However there were specific factors which made energy policy an early candidate for new policy instruments of privatisation and market liberalisation (Helm, 2007). In particular, demand planning run by Central Electricity Generating Board had failed to account both the economic stagnation of the 1970s; and the decoupling of economic growth from energy demand, a process accelerated by the deindustrialisation of the UK economy during the 1980s. Moreover the formula through which electricity generators were paid for their work as a percentage of their return on investment came under heavy attack for incentivising 'gold plating', the over engineering of plants and network infrastructure to maximise the prices that could be charged. The result by the late 1980s, was a large excess of generating capacity subsidised by the state and via high energy prices. Combined with the Thatcher government's goal of reducing the power of the National Union of Mineworkers, a decision was taken to fundamentally reorganise the UK energy industry, with economic rationality providing the central organising principal (Hammond, et al., 1985; Helm, 2005; Pollitt, 2012). The tools of this reorganisation included the economic rationalisation of the UK coal industry; the partial removal of subsidies and unbundling of vertically integrated electricity and gas generation, transmission and retail utilities; privatisation; and the introduction of competition in the form of separate wholesale and retail markets for electricity and gas (Green, 2007; Pollitt, 2012).

The shift from Keynesianism thus saw the wholesale abandonment of a pre-existing policy community dominated by planners; regulated industries and an institutional framework to support the planned construction and running of nationalised energy supplies. In their place emerged a community of economically liberal policy makers; think tanks; interest groups in finance and the old regulated industries, united by interests in or ideational commitments to market and quasi market

mechanisms (Mitchell, 2008). This shift can be seen as reflecting not merely a change in goals but a fundamental challenge to the paradigmatic structure of ideas and institutions UK energy policy in which prior belief in the capacity of the state to plan and deliver energy efficiently was displaced by a new set of ideas around competition and economic efficiency. Speaking in 1982, Secretary of State for Energy Nigel Lawson made this explicit;

‘I do *not* see the government’s task as being to plan the future shape of energy production and consumption. It is not even primarily to try to balance UK demand and supply for energy. Our task rather is to set a framework which will ensure that the market operates in the energy sector with a minimum of distortions’ (Lawson, 1982; cited in Helm, 2005, p.7).

This shift is not only reflected in energy. The period from 1979 also saw a dramatic re-articulation of UK industrial policy discourse from a focus on state ownership, subsidies and employment, towards a generalised aversion to being seen to intervene directly and ‘pick winners’ between emergent technologies and firms. Industrial policy gave way to an emphasis on competitiveness characterised by concerns over infrastructure, skills and labour market flexibility (Beath, 2002; Wren, 2001). In short, the state was seen to have no place in the selection of technologies or sectors in which the UK should compete, but would rather be responsible for maintaining a welcoming environment for inward investment and a policy framework which incentivised and rewarded innovation and export.

This understanding of the market as most legitimate and efficient allocator of resources, for a time proved highly successful in energy policy. Newly privatised generators were able to make significant cost reductions through the mothballing of excess generating capacity and sweating of gold plated assets. In the period following full market liberalisation in 1998 to 2003 consumer electricity prices fell by 40% (Helm, 2005, p6). The extent to which market design, network factors and wholesale fuel costs were responsible for this period of low domestic energy prices remains the subject of some debate in the economic literature (cf. Green, 2007; Newbery, 2005), however at the time there was a general consensus in policy that market liberalisation had been a success.

Challenges to the Liberalisation Paradigm

Since the mid-2000s, the liberalised energy system in the UK has come under stress from a range of endogenous and exogenous problematisations. As we saw in Chapter 2, by 2005 energy prices had recovered from their 40% drop and were continuing on an upward trajectory. New challenges associated with the replacement of ageing generation and network infrastructure; the depletion of North Sea oil and gas reserves; and the rise of climate change on the political agenda, all began to come to the fore. The argument made by those claiming a paradigm shift is within sight is that these are challenges for which the liberalised energy paradigm lacks the tools to address (Helm, 2007; Mitchell, 2008). Energy markets designed to drive down costs during a period of over-capacity and prior to the recognition of climate change as a pressing policy issue, while capable of delivering investment in low risk combined cycle gas turbine generation, have been problematized for their failure to incentivise emissions reductions or investment in new low-carbon technologies and generating capacity. Similarly, existing energy transmission infrastructures have been designed to match the predictable output of a small number of coal and gas fired power plants to the consumer demands. Designed to maximise efficient use of generating capacity, this regime is unsuited to the task of managing more distributed, small scale and intermittent forms of renewable generation being proposed to meet decarbonisation targets (CCC, 2011). It is the confluence of these factors with the imperative to decarbonise that have led to the suspicion that a paradigm shift is immanent. This is not to say proponents of a paradigm shift believe this process to have occurred, rather that energy policy has become stuck, unable to fully incorporate the demands of its new context consistently across the system:

‘This paradigm shift in policy objectives has yet to be translated into a coherent set of policy instruments, which have to be grafted onto a privatized and liberalized market structure’ (Helm, 2007, p. 34).

This is not to say all writers agree on what the alternative policy should be. Accounts located in economics and other traditions emphasising rational agency have tended to propose extending logics of market liberalisation by creating markets and prices to incentivise low carbon innovation and investment in new forms of generating capacity (Green, 2007; Stern, 2007). Others however, have been more critical of market based approaches, arguing the automatic endorsement of competition as a goal of energy policy must become secondary to urgent requirements of CO₂ reduction that may require a more interventionist stance than governments have been willing to adopt (Mitchell, 2008; Scrase & MacKerron, 2009, p. 100). This divergence in positions reflects a differential reading of the notion of a policy paradigm. While Helm (2007) does mention ideology briefly in his work, the bulk of his writing suggests that a simple modification of instruments to allow for flexibility in the pursuit of new goals would constitute a paradigmatic shift.

Mitchell (2008) on the other hand recognises the broader ideological and institutional structure surrounding UK energy policy. In particular she identifies the broad complex of a UK 'regulatory state paradigm'; a socio-technical regime which entrenches and privileges the interests of incumbent energy, infrastructural and technology providers through it's highly structured market and legalistic regulatory structure; and narrowly technocratic institutional approach to policy learning and adaptation. Drawing on STIS and transitions theory in particular she argues it is this complex which provides the primary barrier to currently niche level technology providers capacity to influence innovation and regulatory agendas in a transformative way. Fudge et al. (2011) likewise argue that the structuring of markets and policy objectives to ensure low costs, combined with more recent attempts to securitise energy have functioned to reinforce reliance on carbon intensive forms of energy generation. While the mechanisms advocated may differ, there is a general consensus that new technologies and forms of governance are required to at the very least; balance intermittent

renewables; encourage more efficient and responsive transmission networks; and replace insecure and polluting fossil fuels in domestic heating and transport.

Looking to present UK energy policy it is difficult to ascertain whether a paradigm shift; in the broader sense of a consistent set of ideas; institutions and instruments (Hall, 1993) is in fact taking place. The issuing of Renewable Obligation Certificates and Early UK Feed-in-Tariff support for renewable technologies both reflect broadly market based mechanisms, leaving consumers and electricity generators to judge cost optimal technologies to avoid charges or earn incentives for low carbon technology adoption. More recently the 2011 Energy White Paper stated the intention of the UK government to introduce a new market for capacity, including the replacement of the Renewables Obligation with feed-in-tariffs for larger electricity generators. These capacity payments will be banded to reflect the different requirements and benefits of low carbon energy technologies (DECC, 2011), paving the way for long term contracts guaranteeing a price for nuclear energy for a 35 year period. Meanwhile the autonomy of arms-length public bodies in allocating public funds for innovation provides at least a degree of distance between the state and the selection of technology priorities. For Kern et al. (2014), this mixing and matching of institutional goals and support instruments simply represents the contested ideational space around UK energy policy in which competition, decarbonisation and securitisation wax and wane as organising principles for energy policy formation. It is the instability resulting from this accumulation of partially contradictory instruments and narratives that provides the evidence for a paradigm shift in process, or at the very least the layering of new goals and establishment of overlapping institutions for economic and environmental innovation we see in contemporary UK energy policy.

VI. Interests and Power in Transitions Management

Given the developments charted thus far in this chapter, the claim that we are witnessing the emergence of a new paradigm in energy policy towards a greater willingness to intervene in markets and support certain forms of low carbon innovation do carry some weight. However it ought to be noted there is a distinct divergence between the approach taken to innovation in UK policy circles and the more systemic approaches advocated by sustainable transitions theorists. While some states, notably the Netherlands have been explicit in adopting transitions theory inspired approaches to energy innovations; uptake in the UK has been more selective (Kern, 2012). From the development of the TSB, and Carbon Trust at a systems level; and more specific developments of public private partnerships and support for the niche development of HFC technologies, it would appear the UK is moving (if hesitantly) towards a transitions theory inspired approach to low carbon innovation. The selection of strategic technology areas; niche protection for emergent technologies; increasing coordination between public bodies pursuing innovation and sustainable energy (Kern, 2012; Kern, et al., 2014; Winskel, et al., 2014); and development of institutional frameworks to enable policy learning and collaboration (UKHM, 2012), all seem to point at least partially in this direction.

However UK energy innovation policy has been critiqued for the relative lack of commitment to supporting niche actors and technologies. Winskel & Radcliffe (2014) note that as the development of low-carbon innovation policy accelerated in urgency in the mid 2000s, its focus shifted from long term niche promotion to shorter term technology prospects delivered by regime incumbents. While their focus is upon the evolution of the system itself, rather than explanation of why this shift took place; they speculate the interests of regime incumbents to have been at play. For some, this accelerated urgency was, in part, driven by the reframing of energy policy debates in the mid-2000s from a discourse focussed on decarbonisation, to a securitising agenda centred on nuclear energy (MacKerron, 2009; Scrase & Ockwell, 2009; Toke, 2013). Drawing on geopolitical landscape

developments in central Europe and Russia, established policy networks close to the nuclear industry were active promoters of this discursive frame as a means of advancing their interest in the technology. The effect was an increased urgency in diversifying UK energy supplies away from 'insecure' imports, at the expense of fostering long term technological innovation and niche promotion, a process benefitting large technologies favoured by incumbent energy producers such as large scale nuclear; offshore wind and 'clean' (CCS fitted) coal technologies (Scrase & Watson, 2009; Winskel & Radcliffe, 2014). While these effects may have been somewhat overstated (for a discussion see; Toke, 2013), combined with Mitchell's (2008) insiders account of energy and innovation policy processes, such studies suggest the strategic deployment of ideas by powerful actors have had significant effects in shaping the current paradigm and regime for energy innovation.

Although the above studies sensitise us to the role of incumbent power in energy innovation regimes, they do not focus the bulk of their attention at the level of actors. Rather their broadly discursive institutionalist frameworks identify ideas, attributing them to particular interests, without attending to if and how their proponents came by them, nor whether the niche actors affected by them responded. Where we do find studies tracing agents strategic interpretations and ideas in innovation governance is in studies of the Dutch transitions management process. As the first instance in which transitions theory based approaches have been institutionalised in governance processes, its stakeholder fora for innovation planning and policy learning have been studied widely (Brugge, et al., 2005; Loorbach & Rotmans, 2006; Kemp, et al., 2007). In the only study focussing directly HFCs within this process, Hisschemöller & Bode (2011) examine institutionalised stakeholder back-casting processes designed to identify potential routes to HFC energy systems. In so doing they found stakeholders drawn from different niche and regime industries identified highly divergent visions for the technology, drawn from their own organisational experiences and interests. The high level of disagreement combined with a level of confusion as to the expertise claims made by various

stakeholder members, were subsequently given as reasons by the Dutch government for rejecting the visions eventually identified.

In a study tracing the design and implementation of Dutch transitions management policy itself, Smith & Kern (2009) trace the development of the policy network responsible for developing and implementing institutional processes for the consideration of niche low-carbon technologies. In so doing they find a high degree of strategic adaptation on the part of the innovation policy community in an effort to gain legitimacy and the support of regime actors. Advocates adopted dominant Dutch and European policy narratives of energy market liberalisation and knowledge led economic growth which were subsequently built into the structures and priorities of the stakeholder coordination and policy planning institutions established. While successful in gaining policy acceptance, the resulting implementation of the policy was highly technocratic in nature. Representatives of incumbent industries were given senior roles in stakeholder bodies, and the institutional ideas and norms of the existing regime imported into the new institutional framework for innovation promotion:

‘the new institutions created under transition policy – the platforms and experiments – are captured by prevailing policy networks which interpret requirements through existing institutional norms, such as narrow technological costs and benefits, and are constrained by, rather than challenging, current energy markets and infrastructures’ (Smith & Kern, 2009, p. 94)

This critique is echoed in the work of others working within or outside transitions theory approaches which argue that in reducing sociotechnical transitions to niche-regime coordination and multi-stakeholder learning, more transformative concerns over social practices; power relations within regime networks; and public involvement in deliberation processes tend to be lost (Hendriks, 2009; Scrase & Smith, 2009; Shove & Walker, 2007). Pointing to a range of cases of successful low-carbon energy technology adoption in the UK and Europe, Toke (2011) argues such niche technology interests tend to gain greatest influence within energy policy regimes when allied to wider social movements. Acting as both supportive niches for technological adoption and experimentation, and

normative entrepreneurs campaigning for value and policy change, alliances with such movements provide an additional mechanism for niche innovation to influence shifts at the regime level. Such claims find widespread support in literatures on reflexive ecological modernisation which argue, usually from a normative standpoint; that narrow and technocratic governance of energy and environmental energy innovation are unlikely to build the widespread legitimacy required for transformative socio-technical change (Christoff, 1996; Hajer, 1996). In this view, without broader mechanisms to empower niche actors; climate, energy and innovation policy are likely to be drawn into the realm of 'non-politics' capable of sustaining RD&D support but not of influencing wider energy policy goal structures- particularly in fields that may disrupt established regime interests (Meadowcroft, 2009; Scrase & Smith, 2009).

We return at this point to the initial questions raised within the ories of network governance as to whether such practices are best categorised as means to enrol new forms of expertise into democratic policy processes; or whether governance rather functions as a means of further entrenching the interests and power of already privileged groups. These questions cannot hope to be answered within the realms of a single thesis; they stretch back beyond Rhodes' (1996, pp. 661-663) 'hollowing out of the state', past 20th century debates between pluralists and elitists (Bachrach & Baratz, 1962; Dahl, 1961; Lukes, 1974) to some of the earliest conceptualisations of the relations between the state and society. However, in so far as energy innovation governance in the UK reflects relatively virgin territory for this debate, we do not yet know which model may characterise relations within the HFC community. To the extent that the answer to these questions may have significant implications for the form this community might take and the kinds of technology supported within it, sensitivity to these issues would seem prudent.

VII. Summary

Beginning with a critique of narrow rationalist approaches to the study of policy and technological innovation, this chapter has sought to situate this thesis' study of the HFC community in relation to two disciplines and three distinct literatures. Regarding STIS, it identified transitions theory in general, in particular the multi-layered perspective outlined by Geels (2002) as a valuable conceptual framework for considering the community. Specifically it alerted us to innovation as a contingent processes entailing niche; regime and landscape relations that may be constituted through emergent attempts to support HFC technologies in UK energy innovation policy. In relation to policy studies, the chapter presented a typological distinction between four variants of social constructivism in order to highlight the insights each offer into questions of networked innovation governance. In so doing it gradually became clear that while socialisation and learning; discursive institutionalist and deliberative approaches to policy analysis contain significant overlaps with transitions theory approaches, an actor centred constructivist framework provides a conceptual framework for dealing with issues of interest and power transitions theory leaves under -theorised. While these insights provide useful concepts in the following chapters on research design ; methodology and analysis, in the above discussion they provided a means of interrogating the more substantive literature on paradigms in and critiques of UK energy and innovation policy.

Looking to the literature on UK energy policy two distinct trends stood out. Firstly there has been a considerable focus on the notion of policy paradigms as systems of ideas structuring the policy goals and instruments for the management of the UK energy system. In particular there is ongoing debate as to if and how the UK may be moving from a paradigm centred on ideas of energy market liberalisation to a more activist stance centred on low carbon energy innovation and decarbonisation (Helm, 2007; Kern et al., 2014). In drawing attention to policy paradigms as ideational and institutional structures for managing energy system developments, constructivist policy analysis and energy systems research flesh out transition theory concepts of the socio-technical regime and

landscape. More specifically they address the absence in transitions theory approaches of a mechanism explaining how macro-social factors such as transnational ideologies and global environmental change effect regime development. In positioning these factors as ideas, harnessed by strategic action in policy processes; accounts of the policy process as paradigmatic point to actors strategic use of ideas as a key area of concern. Given the uncertainty this literature expresses in terms of the nature of paradigmatic adjustment the UK energy regime is currently undergoing, a key question for the emergence of the HFC community thus becomes the extent to which the strategies of HFC community actors are shaped by paradigmatic ideas of liberalised market competition and low-carbon innovation.

Within this literature we also find something of a disjoint between broadly rationalist accounts of policy change resulting from exogenous factors in global energy markets and concerns over climate change (Helm, 2007; Green, 2007; Pollitt, 2012), and those highlighting the role of interest groups in shaping the discursive institutional structure for UK energy innovation (Mitchell, 2008; Scrase & Watson, 2009). It ought to be noted at this stage, such issues are not unique to energy innovation, they are paralleled in accounts of sustainable transport policy as guided by paradigmatic assumptions about the ubiquity of automobility (Marsden, et al., 2014; Marsden & Docherty, 2013); and work emphasising the power of incumbent road building and automotive manufacturing interests (Dudley & Chatterjee, 2012; Dudley & Richardson, 1998; Docherty & Shaw, 2012). However, despite these literatures' focus on the overlap between interests; power and the emergence of an incumbent led system for 'accelerated energy innovation' (Winkel & Radcliffe, 2014), this work has tended to operate at relatively high levels of analysis, focussing on institutional and system development. As such relatively little attention has been paid to how actors within the energy innovation system (particularly those pursuing niche technologies) have interpreted their interests and developed strategies in the face of such challenges. Studies from the Netherlands, where stakeholder

participation in energy innovation policy making has been more highly institutionalised, suggest pre-existing interests and positions in established sociotechnical regimes have significant impacts upon the ways actors interpret innovation challenges and solutions (Hisschemöller & Bode, 2011; Smith & Kern, 2009). However given the more recent emergence of UK energy innovation as a policy area and the lack of a single formal institutional structure for managing such stakeholder processes, to date there have been no comparable actor centred studies conducted here. As such we can merely take the insights offered by transitions theory and more critical constructivist policy analyses as guides to what we might expect to find within the UK HFC community in practice.

4. RESEARCH DESIGN

I. Interpretivism and Construction

This chapter outlines the process of design from which the research proceeded in its investigation of the HFC community. In so doing it situates this thesis in relation to constructivist and interpretive modes of social enquiry, and argues with Yanow and Schwartz-Shea (2006, p. xviii) that; ‘epistemological and ontological claims are mutually implicating’. Ontological position fundamentally affects the types of research questions we ask, the logics of research design, and the forms and status of data we go in search of. This is to say if we are asking research questions regarding a policy community and the actors; ideas and strategies within it, then what manner of ontological assumptions are we making, and by what empirical strategies might we begin to gain purchase upon it?

These questions guide much of the discussion over the following three chapters. Here the aim is restricted to elucidating how they were addressed during the design phase of the research. This chapter thus outlines how a broadly interpretivist-constructivist ontological position, derived in part from actor-centred constructivist literatures on governance and institutionalism (Saurugger, 2013), was translated into a case study research design specifying the HFC community as (an as yet unspecified) field of interpretive contexts and variation. In explaining how this field came to be gradually bounded as a phenomenon, the chapter then shifts to the basis upon which specific cases were selected to account for the range of paradigmatic interpretive positions within it (Flyvbjerg, 2011, pp. 306-309; Stake, 2005, pp. 459-460). Finally in specifying the study as one seeking to elucidate the HFC community via its variations, the chapter shifts to discuss elements more commonly associated with methodological planning and conduct; in particular the iterative process through which early empirical work informed the specification and selection of cases for inclusion in

the study. Before shifting to these questions however it may be instructive to provide a brief theoretical overview of the type of social reality we might expect to encounter when investigating the HFC community through reference to two analytic traditions; constructivism and interpretivism.

In appealing to constructivist and interpretivist branches of empirical research there is a risk of conflating two distinct traditions. Both share roots in hermeneutics and phenomenology, which provides them with overlapping concepts and terminologies, and a sensitivity to meaning as a foundational element of social reality (Bevir & Rhodes, 2012; Schwandt, 2000). This is to say that for constructivists and interpretivists, ideas and meaning reflect not only human interpretations of events; they define actors and artefacts; specify the possible relations between them, and provide reasons and cognitive maps which shape and motivate human interaction (Hay, 2007; Yanow, 1996). For both traditions, the social world is not merely a collection of material facts waiting to be uncovered but rather consists of interpreting actors who allocate meanings to the artefacts and other actors they encounter. Policy ideas and artefacts are not merely referents to some external physical world, but are the product of meaningful and purposeful social interactions through which subjective and intersubjectively held ideas, values and beliefs are put into practice (Gubrium & Holstein, 2000; Yanow, 1996, pp. 6-11). Put simply, social interaction not only describes the world it actively constructs it. As such, both traditions must contend with what Giddens (1984, p. 20) terms the 'double hermeneutic'; social scientists do not only interpret the social world in terms of its ideas and objects, they must also contend with other actors' interpretations of that world (Hay, 2011, Yanow, 2007). In part due to this, constructivist and interpretivist research carry long standing empirical affinities with qualitative and ethnomethodological research traditions, which focus on the highly contextualised processes of interpretation and meaning construction in talk and text (Angrosino & Mays de Perez, 2000; Gubrium & Holstein, 2000).

This brings us to the main point of divergence for interpretivists and constructivists. For the interpretivist, any actor's interpretation will be shaped by the ideas and institutional contexts in which they are embedded, and will be distinct from and irreducible to the object of their interpretive efforts (Bevir & Rhodes, 2003; Bevir & Richards, 2009). Given this contextual specificity, it follows for the interpretivist that any knowledge gained via interpretivist research is necessarily contextually bounded. This is to say in privileging the moment of situated interpretation and action, interpretivists tend to reject a role for independently existing social and institutional structures in shaping social life (Bevir & Rhodes, 2005).

Critiques of this position have taken two primary forms. Proponents of weaker forms of constructivism have suggested that, shorn of attendance to material and economic structures, interpretivists over privilege agency and interpretation in their accounts of social practice (Marsh, 2009). Conversely stronger constructivist and poststructuralist accounts argue that in emphasising situated 'contextualised self-understandings' interpretivists miss underlying logics of social action embedded in deeper meaning-structures across multiple contexts (Glynos & Howarth, 2008). Hay (2011) offers a more sympathetic reading in which he draws attention to the constraints the interpretivist concept of situated agency places on interpretation and action. Expanding on this concept, he draws on institutional theory to argue that interpretive contexts are not merely the product of actors immediate environments. These environments are also constituted by widespread formal and informal institutions, which become inscribed in the material and ideational resources available to a given actor or organisation. While local contexts may lend themselves to varying interpretations and constructions of agency, they do so in the context of wider institutional structures which shape and constrain the opportunities for situated actors to maintain existing institutional relations; interpret them differently, or more rarely, to construct alternatives to them.

Rather than positing an opposition between constructivism and interpretivism, this thesis is instead content to view them as cognate traditions, whose difference in emphasis can be a valuable attribute in the analysis of empirical data. The benefit of both emphases is captured neatly in the following from Gubrium & Holstein (2000, p. 488), speaking on qualitative analysis in general terms they suggest:

“Interpretive practice engages both the *hows* and the *whats* of social reality; it is centred both in how people methodically construct their experiences and their worlds and in the configurations of meanings and institutional life that inform and shape their reality-constituting activity.” In this view interpretive research should focus on how situated agents’ interpretations are shaped by the diverse institutional meanings to which they are exposed, while maintaining a constructivist insistence that such interpretations are themselves constitutive of those actors and institutions. In specifying both ‘how’ and ‘what’, a constructivist interpretivist analytic framework must seek to trace both what the relevant institutional contexts and constraints are on actors’ situated interpretations and actions; and how situated interpretive processes allow for the construction of particular realities.

II. Research Design: Case Study Research and the Importance of Context

In coming to the design of the study, the researcher was initially struck by the relatively narrow range of options available for generating data on the HFC community within the confines of a single student PhD study. HFCs are a relative novelty in UK policy discourse and at the outset of the study, the nature of the institutions and community surrounding them were not clear. Indeed, at this stage in the study, the actor centred constructivist position which subsequently served to provide a focus to the thesis had not yet been fully articulated. The very nature of the HFC community as a policy community was itself uncertain. Under such circumstances two options existed for researching the HFC community; survey based designs and case study research. The former would have sought to specify the HFC community via reference to its population and its correlations with a broader range of pre-specified variables. The latter approach conversely aimed for the generation of knowledge in context, focussing on the meaningful nature of social interaction within the HFC community and

providing a narrative description of what was taking place within it (Hakim, 2000; de Vaus, 2001). The case study design eventually alighted upon in this section, further outlined in the rest of this chapter, was the outcome of balancing the potential benefits of each design and practical considerations of how they may be operationalised. However, it is also the product of a deeper ontological commitment to an understanding of the HFC community and policy processes more broadly as characterised by interpretive relations.

Given the thesis's eventual focus on providing an actor centred constructivist account of the actors, institutions and strategies relevant to the development of the HFC innovation governance; it may be argued that some form of economically informed survey design focussed on actor resources, institutional networks and strategies may have provided a valuable means of specifying the nature of this community. However, even were one to approach the topic with a positivistic ontology, and a desire to generate a probabilistic causal account of the actors; institutions; and strategies within it, the scholarly groundwork had not been laid to identify what the most appropriate variables within the population might be, far less to make judgements as to the representativeness of any given sample developed (Ackoff, 1967; de Vaus, 2002). Given the insistence on the role of contextualised interpretation and meaningful action present in the substantive literatures on governance (Saurugger, 2013) and the broader constructivist-interpretivist research literature (Yanow & Schwartz-Shea, 2006); a survey approach seemed to risk prematurely separating out key interdependencies into variables before they could be properly understood and specified. In contrast case study research does not require the pre-specification of interpretive variables. Instead it relies on the flexibility to collect multiple forms of data and engage reflexively with the actors involved to develop rich, contextually bounded accounts of the key variables at play (Flyvbjerg, 2006; Stake, 2005; Yin, 2003). The author follows Flyvbjerg (2006) in rejecting the suggestion that such knowledge is only useful as a primer for subsequent research deemed to be more representative and

generalizable. However, in this instance even were one to subscribe to such a view, the relevant case knowledge that would be required to specify survey variables was lacking.

By adopting a case study approach, we must recognise the trade-offs that accompany the design. While there are strong philosophical grounds for doubting the claims of any form of social research for generating wholly objective knowledge (cf. Flyvbjerg, 2001; Giddens, 1987; Sayer, 1992), it is nevertheless the case that case study research is irrevocably dependent on the context in which it is produced. This is not to say such knowledge can never be generalised. Knowledge of a given case may be of intrinsic interest in and of itself, or (provided sufficient contextual detail is included in research reporting to judge its applicability) it may be translated to broader classes of similar phenomenon (Adcock, 2009; Benchofer & Paterson, 2000, pp. 47-49; Lincoln & Guba, 1985). HFC technologies are positioned at an unusual intersection between energy, transport and innovation policy; and have tended to have a lower, less controversial profile than other emergent technologies (for a range of examples see; Pidgeon, et al., 2008; Rowe, et al., 2005; Shackley, et al., 2005). The policy community emerging around them may be of interest as a case in its own right, and as a single, less heated instance of the broader classes of energy and innovation policy processes. While one case alone may not provide law like causal predictions for these other phenomena, a translation of the context encountered can still be useful in helping scholars and actors from similar contexts understand the practices they encounter. The validity of such knowledge lies not in the degree to which its representativeness has been controlled for, or its capacity to communicate each and every contextualised experience in its entirety. Rather its credibility and transferability is dependent upon its capacity to provide a rich explanatory narrative that explains what is going on in a particular context, while remaining faithful to the interpretations of actors located within it (Creswell & Miller, 2000; Hawksworth, 2006). Case study research thus remains credible as long as it can demonstrate prolonged exposure to the context under study; examination and comparison between divergent

cases or instances within it and the meaningful relations between them, and; a degree of reflexivity in its interpretation of the research process and context encountered (Kluge, 2000; Lincoln & Guba, 1985, pp. 289-331; Schwartz-Shea, 2006). Such a task is not the preserve of the process of research design. While this forms the focus of this chapter, these criteria are returned to in subsequent chapters on methodological planning and analysis.

Clearly not all case study researchers subscribe to interpretivist criteria of credibility and transferability. Other research designs have claimed the capacity to examine interpretive processes and constructions of meaning in context. Ragin's (1994) model of comparative case study research attempts to separate key variables and outcomes from 'spurious' contextual factors. Conversely some survey designs, notably those pursuing Q methodology and corpus linguistics have paid particular attention to the construction of meaning in different contexts, albeit at further remove than direct case study investigation (Baker, et al., 2008; Ellis, et al., 2007). Such examples aside however, the predominant research design for studies concerned with meaningful social interaction in a given context have tended to be case studies. Much of the theoretical insight offered by science, technology and innovation studies has been built on historic case studies detailing the actors, institutions and strategies through which emergent innovations come to be seen as successes or failures (Bijker, 1997; Latour, 1988; Geels, 2002). In more policy focused literatures, case studies have been deployed to explore the role representations of nature and institutional categorisation play in constructing environmental governance practice (Liskog, 2014); as well as the role of language and metaphor in the articulation of conflicting policy communities around the issue of airport expansion (Howarth & Griggs, 2006). Expanding upon this corpus of research could take a thesis in itself, more important here is what this work shares: an understanding of case study research as providing access to the meaningful interactions between social actors, whose interpretations and practices are shaped by their social contexts. Rather than direct causal accounts, they build rich multifaceted pictures of

the interaction between multiple elements in generating new processes of socio-technical governance, whose validity lies in the depth of description and the credibility and plausibility of the accounts provided. It is in this tradition this thesis aims to follow.

Case Specification and Boundaries

Given the decision to adopt a case study design, important questions remained regarding the nature of the case to be examined. While reviews of the literature identified a broad range of governing institutions and problematics relating to HFC innovation, it did not point clearly towards a single institutional or organisational context as the case at hand. This section draws on methodological literatures on case study research and notions of community in the social sciences to outline the process by which the HFC community emerged as a theoretical construct bounding the case under study as the shared context of multiple organisations and institutions oriented towards HFC innovation. Seeking to draw out the multiple representations that comprise the development of a case study, Platt (1992) draws a distinction between the overarching case a study seeks to represent; the individual cases portrayed in its analysis to build a picture of this larger whole, and individual sources of empirical data. Stake (2005) speaks of a case as the bounded object of a study made up of specific phenomena revealed in individual sources and patterns of data. Flyvbjerg (2011) conversely speaks of a general context or phenomenon of study that can be made knowable through examination of particular cases, in which experiential knowledge is a privileged form of data. While each of these trifold accounts brings subtle differences, each seeks to distinguish between the overall object of a study, the analytical concepts through which a researcher makes sense of it, and the base empirical units from which these concepts are drawn. Of these, this section focuses on how the overall object of the study was bounded at the design stage of the research.

It is at this point we begin to encounter some difficulties in specifying the HFC community as an overarching case. In the first instance, let us consider the term community the thesis has deployed so far to denote the range of actors and practices forming around HFC innovation in the UK. In so far

as an understanding of the HFC community is itself what the study aims to articulate, it was difficult at times to anticipate what we may expect to find within it. In the first instance, the term community was applied to the study by accident, an ad hoc linguistic choice made in a supervision meeting to describe the network of formal and informal relationships, organisations and institutions making up the field to be examined. The term stuck, in part due to its congruence with existing literatures on policy communities and networks (cf. Rhodes & Marsh, 1992). While alternate labels such as the HFC innovation network or HFC policy process were considered; the term community more explicitly evoked the complex interactions between institutions and a broad range of social and techno-scientific actors literature on innovation and socio-technical transitions suggested would be encountered.

The question remained however; if an HFC community was to constitute the overarching case under study, on what basis can this community be thought to exist? The notion of community appears in a number of social science literatures. 'Communities of practice' (Cox, 2005; Wenger, 1998); 'communities of interest' (Cantador & Castells, 2011; Henri & Pudelko, 2003) and 'imagined communities' (Anderson, 2006; Beck, 2011) all seek to describe community in relational terms, underpinned by shared sets of concepts, languages and ideas. Yanow (1996, p.47; 2001, p.26) speaks of 'interpretive communities' as symbol sharing groups whose collective experience of organisational and wider ideational contexts means they are likely to interpret policy artefacts and events in similar ways, or at the very least are oriented towards similar policy ideas and artefacts. Taking a more explicitly constructivist turn than Yanow, we may additionally suggest that the community is not merely shaped by its ideational context, but the broader institutional contexts in which such ideas and artefacts are forged (Hay, 2007; 2011). In so doing we may specify the UK HFC community in terms of a grouping sharing a particular institutional context; oriented to an overlapping set of ideas; and concerned with a particular collection of artefacts.

Institutionally speaking, the primary focus on the HFC Community was of its nature as a policy community or network; as such participation within the broader HFC innovation policy process was deemed an essential criteria for inclusion. However given the focus on HFC innovation governance in the round, no restrictions were put in place as to what form participation might take. No discrimination was to be made between the standard phases often described in policy studies textbooks between agenda setting, policy formulation and implementation (cf. Hill, 2009). Rather the key boundary for falling within the HFC community was defined as requiring interaction with UK governmental institutions engaged in HFC innovation. These could be central departments of state or the broader non-departmental architecture they have put in place for techno-scientific innovation. To the extent that some non UK based organisations and institutions were highly involved in UK policy processes these were included in the study, provided they displayed significant impacts on the core policy community under study. In terms of ideas and artefacts, due to uncertainty as to what would be found in the field; the researcher was reluctant to specify in advance the precise forms of HFC technology or ideas about them would be of relevance. While it was possible the HFC community may take the form of a classic policy community, containing a relatively narrow set of actors whose shared organisational and institutional contexts, it was equally possible it would resemble a wider policy network (Rhodes & Marsh, 1992; Toke & Marsh, 2003) involving a range of interpretive communities with diverging ideational and organisational contexts but still oriented towards shared objects such as HFCs and policy making institutions.

Notwithstanding the study's overarching commitment to openness and flexibility, some criteria were essential to maintain focus and prevent the study expanding indefinitely, drawing in evermore tentatively linked actors and institutions into its remit. HFC's represent a broad family of technological artefacts, associated with a broad range of ideas regarding their value and potential

applications. Some means of limiting the range of HFC related artefacts and ideas pertaining to them, was necessary. This meant difficult decisions as innovation theory suggests learning in relatively minor niches may nevertheless generate technological development, cost reductions and user familiarity that facilitate leaps into larger markets (Rip & Kemp, 1998). So progress in niche HFC applications unrelated to energy or carrying relatively minor sustainability improvements due to their small size, are still funded as objects of innovation policy. They may well carry significant implications for future environmental and energy policy. However given the unpredictability of such future developments, and the overarching focus of the study on the HFC policy community in the present day, the decision was taken to focus only on those with the greatest profile within the UK policy process.

In practice this meant narrowing the HFC community down to consider only technologies ideationally linked to large scale energy systems and environmental policy goals. The study opted to focus on those technologies being constructed as artefacts of environmental and energy policy. From the literature three applications were identified as of particular relevance and salience in existing academic and policy discourse; H₂ Fuel Cell Electric Vehicles (FCEVs) and associated refuelling systems; fuel cell micro-Combined Heat and Power (FC mCHP); and Hydrogen production in grid applications (see Chapter 2, pp.14-21). These three applications, while partially distinct in their use of differing fuel cell designs for different purposes were nonetheless linked as objects of energy and decarbonisation policy. Indeed as the study proceeded it became clear that while on occasion HFCs in each application were treated as separate entities, innovation governance often treated them in similar ways and the boundaries between applications was often blurred. As such they formed subgroups of HFC community members the research purposively sought to include, rather than clearly defined cases in their own right. In narrowing the selection of technologies to this group, it became possible to provide a boundary to the ideas and artefacts that would be of relevance to the

study, without pre-empting the possibility that such ideas and artefacts may be interpreted differently by different communities within the overarching case.

In summary, the overarching case the study was concerned with can be defined as a community of actors inhabiting a particular context in UK policy making that is concerned with the competitive, environmental and energy system potential of innovation in transport, domestic heat and power and grid applications. While policy institutions such as departments and public bodies would form central points of orientation for other actors within this context, insofar as they are themselves organisations with agency, they too were to be considered members of this community. Alone however such institutions do not constitute a community, rather the community also encompassed the broader range of organisations which contribute to the policy making processes via participation in agenda setting, policy formulation and implementation practice. In setting these boundaries around the phenomena under study the intention was to provide some focus to empirical investigation, without seeking to pre-empt what may appear in the field.

III. Case Method and Specification

Before shifting to a description of the case selection process, it should be noted that there was never any doubt that the case of the HFC community was one comprised of multiple interpretive contexts. From the process of case specification and the broader academic and policy literatures surrounding HFC innovation policy (see; Chapter 2.V, pp.24-29), it was clear that the HFC community was both geographically and organisationally dispersed; containing a range of institutions such as DECC;, the Technology Strategy Board; Carbon Trust; and public private partnerships, each speaking to larger audiences in policy; academia and industry regarding a broad range of policy ideas and artefacts. Insofar as the literature identified consultancy reports; academic publications and outputs from public-private partnership organisations, these audiences appeared to be speaking back. As such it

became clear that a case study in the classical ethnomethodological tradition of immersion in a single geographic context (for a discussion see; Angrosino & Mays de Perez, 2000), or even a looser interpretivist focus on a particular policy making institution or process (Bevir & Rhodes, 2012; Yanow, 1996) could not capture the variation within this wider community. Rather the study required attendance to context at the communal, inter-organisational level, one capable of moving across the multiple organisational contexts through which the overarching case was interpreted and constructed. While the precise nature of these case contexts proved elusive, specifying them became a key part of the research design process which bled into the conduct of empirical research.

However given the nature of the case study as, in many respects, a scoping exercise looking to characterise the HFC community, relatively little could be specified in advance regarding the individual organisational cases through which that phenomena could be specified. As is discussed in Chapter 6 (pp.122-125), broad headings of 'actors', 'institutions' and 'strategies' gradually emerged as key analytic concepts, guided by knowledge of the case and the development of an actor centred constructivist interpretive framework for the study. However this framework was a product of analysis rather than design. In the early stages of the research there was uncertainty as to whether the actors and institutions in question might exist as individual organisations; formal partnerships or institutions; or less formal coalitions existing at some ideational or discursive level. Research thus began on a somewhat uncertain footing aiming to gradually specify its key units of analysis through early investigative work examining policy literature and in pilot interviews conducted locally at Birmingham.

The lack of an advanced plan for specifying units of analysis as a basis for sample development is not necessarily a problem in case study research. Grounded theorists and other proponents of the design

have long held its capacity to refine its objects of study; collect new data in unanticipated forms and gradually develop analytic units from it is one of its key strengths, mitigating against researcher and instrumental bias towards pre-conceived epistemic frames (Flyvbjerg, 2006; Glaser & Strauss, 1967). Case study research remains free when entering the field to purposively uncover multiple empirical cases which can act as emblematic of particular categories or varieties within an overarching case (Flyvbjerg, 2011, pp. 306-309; Stake, 2005, pp. 459-460). As a point of departure the decision was taken to begin examining the community from two directions in what might be termed a snowball sampling approach (Gillingham, 2005, p. 16; Denscome, 2008, p. 58). At one end research began locally at Birmingham's Doctoral Training Centre for Hydrogen and Fuel Cell Research (DTC); and at the other examining publically available policy documents at the UK national level. In gradually developing experience of the HFC community in this way, it was hoped the researcher might identify both the appropriate case units for the study and expand outwards into them, gradually building a knowledge interpretive variation through the addition and elaboration of new cases.

The rationale for this approach was manifold. At Birmingham the researcher's position as a student affiliated to the DTC provided knowledge of its status as engaged in the policy processes via its funding through the national Engineering and Physical Sciences Research Council, as well as its ambitions for policy relevance and building links into the broader HFC industry. This provided an ideal starting point to acclimatise the researcher to the community under study, and for branching out into it. Attending to national policy documents on the other hand, provided details of industry and research partnerships, lists of consultation participants, and case studies of HFC innovation in practice. They offered early indicators of additional cases where the study might expand. By beginning the snowball from both ends the research hoped to bypass the need for personal referrals from past cases, thus speeding up the process of case identification and recruitment. Furthermore, the two approaches provided a valuable means of cross-checking one another; policy documents linking to organisations and institutions not directly related to the Birmingham case. In practice and

somewhat unexpectedly the reverse also proved the case, the Birmingham snowball helping to identify several organisations with lower profile in policy literature but still engaged in HFC policy processes.

Case Selection in Practice

In practice the process of case specification and selection was less straightforward than the method presented above. While organisations eventually emerged as the central case units within the study, they did so not in the design phase, but rather as the result of the researchers early attempts to access and make sense of the HFC community in practice. In this sense the research resembled Janesick's (2000) description of qualitative research as improvisation with initial plans requiring ongoing contextual interpretations, analytic judgements, and re-adjustments in order to remain appropriate to the task at hand. Initially an approach informed by critical and poststructuralist iterations of discourse theory had been anticipated (Fairclough, 2003; Howarth & Torfing, 2005). Within this strategy, paradigmatic variation would be outlined through the identification of discourse coalitions; symbol sharing groups united by shared storylines and systems of equivalence and differentiation uniting disparate techno-scientific ideas about HFCs in the policy process (Hajer, 2005; Howarth & Griggs, 2006). However early examination of language in policy relevant documentation and interviews at the Birmingham site did not initially reveal obvious divergences in symbolic representation through which interpretive variation could be clearly demarcated. What they did point to however were notions of partnership and collaboration within which organisational actors were positioned as key organising units in the process of HFC innovation governance.

The actual process of case selection proved highly iterative; beginning with desk based research and collection of documents. Extending into Birmingham interviews it involved the gradual refinement of the units of analysis away from discursively constructed coalitions to distinct organisations identified

in policy documents and interviews. At this point in the identification and recruitment of cases to the study, decisions had to be taken to ascertain whether a case was relevant to the study, and if so what it might contribute to the elucidation of the overarching case of the HFC community. To facilitate this documents and early interview accounts were initially scanned for an overview their content. Such literal readings (Mason, 1996, p. 109), sought simply to identify the key ways these texts constructed the HFC community and their position within it. During this process, a stand out feature of interviews and policy documents were references to collaborative institutions; a range of organisations and practices tied closely to the conduct of HFC innovation governance via collaborative planning and consultation and state funded innovation projects. Whereas these initial readings had not indicated the existence of particular discursive formations, they did point to a more basic level of variation between the organisational actors they cited as participants in collaborative processes. In line with the snowball sampling approach specified in the design, the data collection process thus sought to expand from policy documentation and the initial site to cover these broader collaborative processes. This marked the first adjustment towards organisational actors as the key case units in the study. In cases of high profile collaborative organisations; trade associations; governance institutions and some collaborative projects, a distinct collaborative identity existed in the form of websites, brochures and other organisational literature. In other cases no such organisational identity existed, and information was sourced from documents emanating from individual member organisations.

It was at this point case selection began to shift towards its final form with organisational actors as the primary cases under study. The rationale for the shift lay not only in the practical requirements of finding documents speaking to a given collaborative process. In interviews referring to collaborative practices, participants continued to identify with the organisation directly employing them rather than the collaboration itself, outlining distinct strategies and rationales for their participation. This

was the case even when such participants were recruited explicitly because of their participation in a particular collaboration. This is not to say every single collaborative process within the HFC community was examined in detail, nor that the cases examined aimed for total coverage of any single collaborative process. Rather organisations were selected for their relative profile within the HFC community, that is to say repeated involvement across a range of collaborative practices. Such decisions were not quantitative in nature but rather reflected the researchers' judgement that the profile accorded to particular organisations in policy documents and preceding case interviews.

Early on such judgements proved difficult to make, and a gradual sensitising process of reading and listening was required before the researcher felt confident in identifying key cases. This process went beyond the formal data collection process and included developing a familiarity with the HFC industry press; discussion groups on open access social media platforms and attendance at a number of HFC specific conferences and networking events. Indeed it was at such events where first contact was made with several future interview participants. In many respects such activities stemmed from the researcher's dual role as a student of Birmingham's DTC and a range of representational responsibilities that came with it, however these activities fed into the research process, providing invaluable contextualised knowledge and expertise (Flyvbjerg, 2001), which aided in the identification of emblematic cases. Thanks to this process earlier case selections rooted in more rudimentary distinctions between organisational purpose or contexts such as academic research, industrial production or policy making and delivery could be refined and built upon. Future selections became increasingly guided by insights from prior interview accounts and documentary research, suggesting gaps and forms of collaboration not previously considered. It was only at the point at which such emblematic insights ceased to be forthcoming that case selection ceased.

In focusing on organisational actors as participants in collaborative practices, the case selection process constructed a particular empirical view of the HFC community; one whose basic case units consisted of organisational actors. In so doing the focus of the study necessarily attended to higher-level participation in policy processes, conducted primarily by senior figures within these organisations and expressed in their officially sanctioned public documentation. As such the HFC community the study speaks to has been rooted at the senior level. Experience of the field and informal conversations with interview participants in the community gave no reason to suggest any major emblematic positions on HFC innovation governance outside these official positions. However it remains possible alternative interpretive positions relating to HFC innovation processes may be held within organisations, by staff situated lower down organisational hierarchies. Given the focus of the research on the governance of the community, as opposed to that of a specific case organisation; the multi-case design and selection method adopted had limited capacity to capture such lower level variances. While regrettable this was to an extent the result of the sheer size of the UK HFC community (the limits of which were uncertain prior to the conduct of the study), which necessarily limited the level of background data that could be collected on organisation encountered.

Moreover, given the case selection process adopted, the research does not claim to cover every collaborative practice through which HFC innovation governance in the UK has been constructed, much less total coverage of all individuals involved to some degree in the HFC community. As such the design and process adopted does not claim its validity either from its correspondence to the total population of the HFC community, nor from a grounded theory ideal of theoretical saturation at which no new insights could be generated from further immersion in the context at hand (Glaser & Strauss, 1967; Bowen, 2008). Rather the criteria for ceasing data collection was one of narrative adequacy (Creswell & Miller, 2000; Hawsworth, 2006); this is to say the researcher was confident that the broad range of paradigmatic positions within the HFC community had been elaborated to a

sufficient level to explain what was going on within it. Confidence in this respect was not the prerogative of pre-established hypotheses or criteria. Rather it was informed by the interpretations and constructions of HFC community actors in interviews and documents; and the researchers growing sensitivity to the overarching context of the HFC community (Flyvbjerg, 2001; Landman, 2012). While further data can always add nuance or serve to refine any case study narrative, a point was reached when these nuances reached a level that could not be communicated within the confines of eventual research reporting without undermining the coherence and explanatory value of the account. However, it was only when this point was reached that the process of case selection and data collection could claim a credible account of variation within the HFC community.

IV. Summary

This chapter has sought to outline the process by which the HFC community was constructed as an object of empirical enquiry. The beginning of the chapter provided a brief introduction to the interpretivist-constructivist position adopted in the design and conduct of the research, and outlined how the adoption of such a position; combined with the practical challenges of conducting research into a relatively unknown policy community, informed the adoption of a case study research design. In specifying the HFC community as the overarching case, the chapter bounded the phenomena under study as a relational field of social interaction taking place around UK energy and innovation policy processes. This is not to say the research anticipated its object of enquiry to be a single interpretive community, rather it was expected the research would encounter numerous interpretive contexts through which the HFC community would be interpreted and constructed in practice. From this discussion, the chapter moved to a longer discussion of the iterative process of design and investigative research through which the study gradually came to focus on organisational actors as the key case units through which the overarching case of the HFC community could be specified, through reference to emblematic variation between them.

Two initial sites were chosen as starting points for the study; Birmingham and publically available national policy documentation. However this decision was taken on the understanding that the empirical case units through which the overarching HFC community would be elucidated were not yet set in stone. Rather these sites formed starting points for the gradual specification of organisational actors as the key case units for the study, and the case selection and recruitment process that would snowball from one site to another. This process was not something which could be pre-specified in advance but required the gradual emersion of the researcher in the overarching case of the HFC community, and the growing capacity to interpret how and why particular organisational actors were accorded prominence. Proceeding in tandem with the conduct of the research and initial attempts to make sense of the phenomenon encountered, this process is perhaps best likened to Flyvbjerg's (2001) notion of phronesis and Janesick's (2000) concept of improvisation; wherein gradual development of context dependent expertise allows for the conduct of more sophisticated research practice, grounded in knowledge of the case at hand.

Finally the chapter returned to the key criteria through which the study claims validity, in particular those of emblematic variation and narrative adequacy through which the researcher was able to judge the point at which case selection, and thus the overall data collection process could cease. While rooted in interpretivist principals of thick description, attendance to context, judgements as to whether such criteria had been reached were not easy to make. However in any study a point must come when the decision is taken to leave the field. In this instance the criteria for doing so was specified as the point at which the data collected was judged to have ceased yielding new emblematic divergences between cases. It ought to be remembered at this stage that this represents a somewhat stylised account of the research design and case selection process; some conceptual tidying has taken place to aid in the communication of what was a complex reflexive process. Where

loose threads remain visible this is a testament to that process, reflecting the essential unknowability any interpretive researcher experiences prior to entering the field. In cases such as the HFC community where the limits; variation and analytic status of the units within it are uncertain in advance, some such messiness is to be expected. The strength of the design adopted was its capacity to reflect upon and respond to the contingent, and uncertain contextualised encounters empirical research throws up.

5. METHODOLOGY

I. Research Methods and the Status of Empirical Data

Having outlined the process of design through which the overarching case and individual analytic cases were specified, the next task was to design a methodological approach capable of putting this into practice. Given the blurred lines between the overarching case specification and the process of empirical research, we arrive at this discussion having already noted several issues informing the data collection process. Notably in specifying the HFC community as the overarching context for HFC innovation governance, the previous chapter identified the need for the research to cover a broad range of organisational and interpretive contexts or cases within it, effectively ruling out single site observation as a methodological approach. In not focussing on a physically bounded community or organisation but the more abstract construction of “the HFC community”, the research opted to focus on the empirical moments when that community became manifested in talk and text (Rose, 1999, p. 55). Due to the breadth of the HFC community such moments could not be observed directly. Documents and interview accounts served as proxies for the broader field of social or organisational interaction and collaboration that constituted distinct the overarching case of the HFC community. While organisations representing key interpretive contexts formed the cases or analytic units to draw from, interview and documentary texts guided the key empirical moments, units of observation or data that was to be collected in practice (Ragin, 1987, pp. 7-8). This chapter aims to fill in the methodological detail of how this data collection processes was conceived and functioned. More specifically it details the collection of some 149 documents for analytic examination and the generation of 31 semi-structured interviews accounts, corresponding to 30 case organisations. In so doing it covers three distinct areas; the status accorded to documents and interviews as units of empirical data; the strategies through which such texts were collected or generated, and; the procedures put in place to ensure the research was conducted in an ethically justifiable manner.

Before turning to the more procedural aspects of data collection, it is first worth outlining why a dual approach of documentary research and interviewing was preferred. After all, if we accept that at least some detail on the HFC community existed in policy documentation, how can one justify the more time consuming and invasive step of interviewing? There are two key rationales for this decision. The first stems from the fundamental differences between the genre and interactivity of documentary and interview accounts. The former provides relatively fixed 'official' constructions of organisational position; the latter allows for a more interactive re-construction of the interpretive processes and logics through which such positions are arrived at (Silverman, 2001). The second rationale for conducting interviews was as a means of ensuring the credibility of researcher interpretation. As an outside interpreter entering a new context, interviews provided the researcher with a means of checking their own readings of documentary evidence and subsequent analytic attempts were sufficiently rooted in the knowledge of community members.

The primary rationale for opting for interview and documentary modes of data collection was the sense in which texts emanating from interviews and organisational documents belong to fundamentally different genres. The public domain document (while containing multiple sub genres within it) is defined in part by its publically accessible, yet fixed nature. Documents may anticipate a multiplicity of dialogical relations with a range of audiences (Bakhtin, 1986). However to the extent immediate interruptions, questioning or response are impossible, the document remains relatively fixed. In many cases such texts represent the outcome of multiple negotiations and editing process between the author(s), and the organisational context in which the document is published. In this sense they reflect an officially recognised or sanctioned organisational position (Silverman 2001). This is not to say documents communicate some true organisational intention or identity. Often they provide contextually bounded 'crystallisations' of organisational strategy at a particular point in time; offering insight into how the organisation seeks to construct itself in relation to the readers it

anticipates (Fairclough & Thomas, 2004, pp. 381-382; Tracy & Tretheway, 2005). Furthermore to the extent that such texts carry a performative power, they can tell us much about the practices of various organisational or case contexts (Bourdieu & Wacquant, 1992; Yanow, 2000). In listing organisational rules and structures, categorising actors and practices and constructing a public identity and purpose for a given organisation documents provide unique access to the overarching grammar through which meaning is constructed in a given interpretive community.

In contrast the research interview, conducted under conditions of confidentiality and partial anonymity (for a discussion see below, pp.110-113), anticipates a singular interlocutor. It makes possible interruption, immediate response and questioning, and in some instance facilitates forms of utterance and positioning that a participant may be reluctant to make more publicly. In this sense, the interview transcript represents a co-authored or co-constructed text; wherein interviewer and participant combine in the articulation of position (Holstein & Gubrium, 1995; Kvale, 1996; Silverman, 2001). If discourse is to be conceived as a series of strategic choices and identifications selected from a broader field of linguistic options (Thiesmayer 2003); interviews offer the researcher opportunity to probe the choices made in formal documentary accounts of policy processes, examining the silences and interpretive processes that allow for particular meanings to be constructed. Combining these approaches gives the capacity to examine both the officially stated public positions of various organisations within the HFC community, but also to reactively probe areas not always covered in an organisation's public discourse; the institutional logics and rationales through which actors interpret their position within the HFC community and develop strategies for action within it.

The second rationale for a dual track approach lay in practical issues which emerged during the early stages of methodological development and data collection; in particular challenges in judging which documents should be collected and how they should be interpreted. This was not interpretation in the formal analytic sense, but rather in the sense of ascertaining the role of particular documents and statements within them in relation to the overarching community. In short, how could the researcher tell their interpretations of documents corresponded to those of its authors and intended audience? Moreover, when it came to individual case organisations, how could the researcher judge the most important details of organisational context from the mass of product, financial and corporate information often published by organisational actors? Confronting such issues, interviews were first envisaged as a means of crosschecking and validating researcher interpretation, and identifying key features of organisational context that could inform the collection and interpretation of documentary evidence. Interviews thus provided a valuable opportunity to engage with members of the HFC community as experts in their respective fields; individuals with volumes of tacit knowledge and expertise negotiating the field developed in some cases over whole careers (Gubrium & Holstein, 2000; Flyvbjerg, 2001). As was discussed above in relation to case selection, early interviews, along with attendance and informal discussions at HFC community conferences, thus played a central role in providing access to practical knowledge and experience of individual case contexts, allowing the researcher to refine their selections and readings of organisation documents. Similarly later interviews provided fora to cross-check initial early interpretations of the HFC community with members operating within it, ensuring no significant cases of variation were missed and that initial analytic concepts bore credible relation to the interpretations of HFC community members.

While it is wise to be sceptical of assuming contextualised expertise can be mined and accessed free from the interpretation of the interviewer (Kvale, 1996); conducting documentary and interview

research side by side, at least provides the opportunities for flagrant mistakes and misunderstandings to be identified early, ensuring at the very least the production of a credible interpretation of the key actors and ideas in play (Lincoln & Guba, 1985). The aim here was not some form of triangulation in the positivistic sense of discovering a 'truth' lying somewhere between multiple biased or anomalous accounts. In line with the interpretivist philosophy outlined above, it was rather part of a broader process of articulating a thick description of the HFC community that captured the multiplicities within it, grounded in the practices and identities the community itself identified as central.

The decision to collect documents and generate interview accounts reflected the distinct advantages offered by each form of data, and the additional benefits garnered by combining them. Publicly available documentation facilitated a far broader coverage of the HFC community than would have been possible in interviews alone. Once greater sensitivity to the overarching context of the HFC community had been established it often gave the basis for selecting individual organisational cases for interview recruitment. Interview recruitment across multiple case sites is a time consuming process, and initial documentary research helped to ensure cases were selected to ensure maximum variation between interpretive contexts might be achieved. At the same time documents provided valuable insights into the recognised categories and practices through which the actors in the HFC community constructed their collective interactions, and the positions they sought to adopt within it. Interviews conversely allowed a degree of interactivity, permitting the researcher to delve deeper into the organisational contexts and interpretive processes that gave rise to particular constructions of meaning; probing the silences and unarticulated logics underlying more formal documentary accounts. At the same time the interactivity of interviews provided a means of checking researcher interpretations both in their early attempts to make sense of documents, and in latter analytical efforts to make sense of the broader HFC community.

II. Data Collection

Having alighted upon documents and interviews as the empirical units most appropriate to the research project the next task was to collect them. Having already partly discussed case selection issues in the last chapter, this section jumps straight into the more procedural aspects of document collection and recruiting interviewees. In practice data collection ran in tandem with case selection. At times this chapter will refer back to the case selection process to show how documents were chosen as relevant to collaborative institutions or organisational actors. Similarly while this chapter devotes separate sections for documentary data collection and interview recruitment, this is to present as clearly as possible the process undertaken, rather than how that process operated in practice. In reality, the collection of documents, recruitment and conduct of interviews was a mutually constructive process with each informing the other. Insight from interviews shaped and refined the collection of documents as much as documents aided in the identification of interview participants. However, in writing up case research some methods are required to untangle the complex contextualised relations experienced for the benefit of the reader. Distinguishing between interview and documentary data collection may seem somewhat artificial but it offers the clearest means of doing so.

Collecting Documents

Interview recruitment and documentary data collection largely took place simultaneously. The preliminary intention was for case selection and recruitment to be driven primarily by documentary research. As such document collection ranged widely from news reports, policy texts and many organisations outside the 28 organisations refined for interviews. Indeed the 149 documents deployed in analysis were drawn from 62 organisational and institutional cases (See appendix 1, p.244-288 for a full list), only half of which were covered directly in interviews. This asymmetry reflects the role of documentary data collection in sourcing contextual background on the overall

HFC community case and informing the pick of emblematic cases for interview recruitment. The whittled down range of organisational cases culled for interviews reflected the outcome of extensive documentary research aiming to classify the wide range of collaborative institutions within the HFC community, and emblematic variations within and between them. Such variation was ascertained in a number of ways. Beginning with documents emanating from policy actors, key institutions for the delivery of HFC innovation were established in the form of government departments and bodies with responsibility for facilitating HFC innovation. Looking to documents coming from these bodies, in particular press releases; funding calls; and policy briefing documents, a range of partnerships were identified containing a spectrum of non-state actors in industry and academia. This led to swathe of organisational actors participating in policy partnership practices.

This is not to claim actors occupying every potential subject position across the HFC community were chosen for interviews or detailed documentary data collection. The field was far too vast for practical coverage. Rather organisations were selected on the basis of judgements as to their relative importance within the broader community and the likelihood of them displaying significant differences in the way they interpreted participation in the HFC community. Documents from all national policy actors were examined in detail on the basis of their centrality to the community at hand. Below this, two local authorities were also selected as emblematic of a broader range of policy actors pursuing HFC innovation at lower scales. The remaining cases were drawn from high profile partnerships to reflect the mixture of organisations within them by size, market or academic focus and the HFC application of interest. The key here was not to generate total coverage of the HFC community but to capture as broadly as possible the archetypal range of institutions, interpretive positions and contextual variation within partnerships and policy processes. During data collection, one institution modified the overarching definition of the HFC community specified in the research design phase. Despite being largely outside of UK centric policy process, the European Fuel Cells and

Hydrogen Joint Undertaking (FCHJU) appeared prominently in documentary and interview accounts of UK HFC innovation governance. Its significance is discussed further in Chapter 7 (in particular, see; pp.165 & 172-3). For now simply note that this caused the FCHJU to be included as a distinct case within the study to shed light on the logics and power dynamics within parallel UK policy processes.

Once an institution or organisation was picked as potentially relevant, an initial search of its website and organisational literature followed. Organisations report in many ways making it impractical to define distinct types of document to be collected in advance. Determining the meaning and efficacy of documents remained a task for subsequent analytic interpretation (discussed below in Chapter 6). Nevertheless, collecting documents for this purpose would have been impossible without some on the spot research judgement about their relevance to the project and likely importance within the wider HFC community (Janesick, 2000). Here the subtle distinction between literature review, data collection and analysis began to break down. Decisions had to be taken quickly to ascertain whether a text was relevant and, if so, what it might contribute to ongoing interviews and in later analysis. To help this, earlier literal readings made during case selection were expanded to generate second order interpretations (Mason, 1996). While not of the final order reflexive and comparative nature later developed in analysis, such readings allowed for the identification of key documents speaking to the context a given case organisation inhabited and their position within it. In practice however a number of documentary genres emerged as key data collection points. Policy briefings and documents pertaining to competitions for state funding were material to analysing organisational categories, goals and practices HFC community members deemed essential to HFC innovation. Conversely press releases; corporate brochures reporting and organisational websites proved particularly useful as early indicators of the interpretive contexts through which organisations developed strategies for participation in the HFC community; providing an invaluable early indicator of variation for subsequent interview recruitment. Once identified these documents were annotated

and saved in electronic format, along with references to and quotations from the webpages on which they first appeared for more detailed analytic attention later.

Interview Recruitment

As mentioned earlier, identifying case organisations for interviews and recruiting participants for them was heavily informed by documentary research. As a more theoretically complex, interactive method of data collection, the process of interview design and conduct is reflected upon in more detail in subsequent sections on interview design and ethics (beginning on p.99 and p.109 respectively). Here the task is simply to provide an overview of the interview recruitment process to give some insight into the nature and scope of cases in which interviews were conducted, and provide some comments as to how these related to the overarching account of the HFC community the research was subsequently able to develop. In the interest of covering the maximum ambit of collaborations and potential interpretive positions, organisations with experience of multiple partnerships were distinguished from press releases and websites. Where possible documentary reporting and previous interview referrals were used to identify the named individuals leading prospective cases HFC innovation, governance and/or partnership activities. Elsewhere chance encounters at conferences and other networking events fostered first introductions to future interview participants. Where this was impractical, telephone and email approaches to the media enquiry contacts on press releases or the generic website contact information proved useful. Initial emails checked the most appropriate staff member responsible for collaborative governance practices was being approached. Once spotted, introductory approaches were followed up with a formal recruitment letter (an anonymised sample of which can be found in Appendix 2, p.256) detailing the purpose of the study and the reason why the individual in question was being approached. Interview arrangements were then agreed by email or telephone depending on the preference of the participant.

In a number of instances the initial staff member identified for recruitment was unwilling or unable to participate for a range of reasons. In one instance availability constraints led to the researcher being referred to another member of staff, and in three cases, multiple interviews were conducted within the same organisation to cover its involvement in multiple policy relevant processes. In another three cases, participants agreed to be interviewed on the condition that they not be quoted or referred to directly in research reporting. The only instance where a significant gap emerged was in relation to civil servants working at the UK national level, only two of whom were prepared to have their interviews quoted. This reluctance, combined with the official published discourse of government departments on HFCs itself proved a useful indicator of how policy actors interpreted their role in innovation governance. Similarly, two representatives of industrial gas companies also agreed to interview but opted out of subsequent quotation, however unlike civil servants, the reason for these opt outs was less clear. The interviews themselves contained little in the way of controversy, or anything which may be construed as sensitive information. Possibly there is something particularly cautious about employees in this sector. However nothing else about these interviews suggested this was the case, nor did the accounts generated differ substantially from those of other large industrial companies interviewed. The researcher is thus inclined to attribute these opt outs as coincidental anomalies rather than to a particular pattern.

In any case, these unquoted interviews served to hone interpretation of documentary sources and the interviews of others which proved more than adequate for the purposes of presenting and illustrating analytic points and research findings. While it would have been useful to point to quotations from these interviews in the presentation of research findings, there were no instances in which interview accounts provided the sole source of eventual findings. In unquotable cases it was thus always possible to substitute key quotes for more generalised comments; comparable passages

from public domain documentation; or confirming statements from other quotable sources. Despite the interview recruitment process causing some minor absences in what could be presented, we can remain confident this has not substantially altered the overall findings of the study.

In total approaches were made to some 38 organisations of which 28 consented to some form of interview. Of the 10 organisations that declined, three failed to respond to initial enquiry's made to named individuals or central contact points. Of the other refusals, reasons given related to time and personnel constraints; or in two cases reference to pre-existing non-disclosure agreements that would have prevented speaking to key partnership or collaborative activities they were engaged in². Regrettable as these refusals were, in each instance alternative case organisations occupying similar institutional positions were found for interviews. While divergences in personal and organisational context would inevitably have led to subtle differences in emphasis had interviews been possible with alternate staff members or at alternate case organisations, from the preceding documentary research the researcher could be reasonably confident that the emblematic variation the research sought to speak to had been covered in a systematic fashion. Given the confidential nature of interviews, it has not been possible to provide a full list of case organisations participating in interviews, however Appendix 3 (p.256) provides a breakdown of these organisation by the sector in which they are based and the actor type to which they were subsequently classified as during analysis.

² Interestingly staff at other organisations subject to the same non-disclosure agreements did feel able to participate without contravening their requirements. Given the widespread use of such agreements within the HFC community; the lack of reference to commercially sensitive information in interviews and introductory correspondence; and reassurances given on participant rights to withdraw from the study, the researcher suspects such refusals were more likely to be excuses rather than genuine reasons for non-participation.

III. Interviewing as Practical Accomplishment

Methodologically speaking, once issues of sampling had been addressed the collection of documentary evidence for this study was relatively straight-forward. As a more invasive form of data collection, interviews required some additional thought. At the end of this process 28 interviews had been conducted, each lasting between 30 and 95 minutes, including six telephone interviews. The process through which these were developed is the focus of this chapter. At the outset of the research, numerous potential interview techniques were considered, all falling somewhere on a scale between unstructured, narrative forms of interviewing on the one hand, and more tightly focused semi-structured interviewing on the other (Gillingham, 2005). In the former category, the less structured approach offered benefits in allowing participants to identify in their own terms what they thought to be central to collaborative practice.

This is not to say interviews aimed to generate some naturalistic discourse of the HFC community in the style of direct speech analysis or ethnographic observation, but rather to provide participants with the space and flexibility to lead the discussion, drawing on discursive resources that may not have been anticipated in advance. At the extreme end of this category there was an initial temptation to use interviews as a means of collecting a corpus of texts that could represent the naturalistic discourse of the HFC community in a style more suited to ethnographic observation and interviewing (Lampropoulou, 2012). In the latter category, literature on 'elite' and other knowledgeable interview participants recommends high degrees of preparation, and clearly delineated topics and areas of questioning. This higher level of structuring reflects the nature of interviewing an expert witness both in terms of restricting (what is often time limited) conversation to those areas of the participants expertise most relevant to the research, and the need to demonstrate appropriate levels of respectful preparation in order to develop and maintain rapport with elite participants (Healey & Rawlinson, 1993; Mikecz, 2012). The preparation for fieldwork constituted a balancing act between a desire to leave space for conversations to lead in unexpected

directions and allow participants space to articulate their own positions, whilst at the same time providing a structure to steer discussion to the most relevant institutions and interpretive processes in a timely and professional fashion.

In planning for interviews it was decided that Holstein and Gubrium's (1995) active interview would provide the best format to achieve this balance, providing space for the interviewer to guide conversation to areas of interest and offer stimuli in the form of questions and prompts to be interpreted and responded to by the participant. This format envisioned the researcher in the role of co-enquirer, seeking to develop a negotiated and mutually meaningful account of the participants' position and practices within the fuel cell community. Interview accounts did not try to achieve a Habermasian perfect communication situation in which agreement over a true meaning is revealed. As an anti-essentialist enterprise, active interviewing proposes that participants will identify with multiple institutional rule sets and interpretive positions in relation to different topics and phenomena. The task for the interviewer is thus to offer a range of potential identifications in their questioning, and assist in building upon and clarifying those positions adopted. The account generated thus does not claim to represent evidence of some true belief or subjectivity. Rather it should be seen as the product of a negotiation in which the participant seeks to position themselves in relation to the interviewer and the topic under discussion, that is practically adequate to aiding the understanding of both parties (Silverman, 2001; Holstein & Gubrium, 1995).

Viewed in this light, the process of interviewing is fundamentally a discursive enterprise in which together interviewer and participant choose, from a range of linguistic options, the most appropriate repertoires to collectively make sense of a particular topic. Unpacking this further, Kvale's (2007, pp. 74-75, see also; Rapley, 2007) brief discussion of discursive interviewing outlines three distinct aims;

(1) that the researcher is sensitised to the potential differences in discourse and understanding between themselves and the participant; (2) pays close attention to the range of discourses in play; and (3) seeks to facilitate a varied exchange through adopting a conversational style and making efforts 'stimulate confrontations between the different discourses in play'. A schedule for an active interview seeking to develop understanding of the HFC community demanded both a relatively narrow range of topics to focus conversation while, at the same time, leaving space for interviewer and participant to negotiate a range of institutional and interpretive positions that shed light on them.

Topic Guide Development

Given the dual commitment to structuring topics and interpretive flexibility active interviewing required, it was decided a flexible topic guide would be more appropriate to the study than a rigid interview schedule. This guide (presented in full in Appendix 4, pp.258-293) contained both the introductory script for the interview, explaining the purpose of the interview and briefly reiterating the range of topics to be discussed, and, a broader selection of issues and prompts to the researcher for reference during the discussion itself. The interview itself was introduced as a 'conversation with a purpose' to manage interviewee expectations about the loosely structured questioning process and authorising the participant to respond to specific questions at whatever length they deemed appropriate. On several occasions this introduction was met with a degree of surprise by participants who, often coming from a natural science background had preconceived ideas equating social research with more structured interview and questionnaire methods. In the overwhelming majority of cases this introduction performed well in paving the way for relaxed and varied interview discussions which covered the range of topics intended in the complexity and depth intended.

As a reference point for the researcher the second part of the topic guide contained an indicative list of topics, potential questions and prompts to guide interview discussion. Given the somewhat nebulous and theory laden conception of the study's research questions, the guide was constructed according to Wengraff's (2001, pp. 111-149) recommendation that such questions be translated into more readily accessible formats in order to invite engaged, open ended narrative responses. To facilitate this, topic guides were designed to offer concrete reference points around which participants would be free to construct their responses. Four broad areas were identified from a combination of the literature along with some researcher intuitions, a full topic guide template can be found in Appendix 4 (p. 258) but these can be summarised as covering:

1. Institutional/Organisational setting in which the participant was based
2. Practices central to the participants work
3. Relationships with external parties
4. Narratives or visions for HFC technologies

Within each topic category, the researcher attempted to balance the framing of a rough area of discussion with space for participants to engage in free discussion, guiding the interviewer through what they took to be the key practices and issues in their work. The aim of specifying such broad topics was to restrict discussion to those areas of participant expertise most of interest to the researcher, while generating longer discussion of the institutional and organisational contexts through which they interpreted and constructed their involvement in HFC innovation governance. For example it was anticipated the discussion of institutional/organisational settings of particular practices might trigger dialogue about the historic experiences, ideas and motivations through which actors interpreted their strategic interests in HFC innovation governance. Similarly it was hoped discussion of external relationships and broader narratives of visions for the technology would provide some insight into how participants construed and positioned themselves and their interests in relation to the wider HFC community and other actors within it.

Beneath each topic a range of suggested subtopics and questions were included as potential prompts during interviews. Following from Rapley's (2004, p. 16) invocation to 'just get on with interacting with that specific person', these were designed to be flexible in nature and deployed in response to the flow of conversation within the interview. However some questions were deployed routinely at the beginning of interviews as a means of opening the discussion and setting the tone for open and conversational questioning. In particular, variations on; 'how did you come to be here', and; 'tell me about x' both functioned well as early conversational gambits, the first situating the participant in a domain they felt confident to speak upon. The second 'tell me about' question was occasionally used in this way but more often provided a means of opening up conversation on a new topic that had been introduced by the participant earlier in discussion or to move discussion along to a new topic.

As interviews proceeded, use of the guide became more fluid, with improvised clarifications playing a more significant role. In these latter stages of an interview, the researcher also sought to introduce alternative interpretive frames for discussion highlighting; contradictions emerging within the interview itself; narratives emanating from other typical actor positions or researcher insights from ongoing analysis. Built into the topic guide in the form of 'why...'; 'what about...'; or 'have you considered...' questions, the researcher sought to avoid offering up these perspectives in an oppositional manner but rather sought to adopt the role of devil's advocate. This was not an attempt at some form of 'epistemic interviewing' seeking to test the accuracy of participant accounts (Brinkmann, 2007). Rather the aim was to develop and maintain a 'phronetic' or 'deliberative' interview style (Curaco, 2012; Thuesen, 2011), balancing an open ended focus on the experience and discursive choices of the participant, and a more robust form of questioning seeking to make explicit the contextualised logics through which actors interpreted their involvement in particular practices, partnerships and governance processes.

Given the range of participants the research anticipated; from civil servants to industrial engineers, it was anticipated a high degree of variation would be required in participant questioning. To this end the generic topic guide to be used across interviews was left deliberately vague to accommodate variation between participants with unique organisational experiences and interpretive backgrounds. This applied both to the precise nature of practices to be discussed, and the means through which questions were framed or encoded in languages appropriate to participant contexts (Foddy, 1993). These generic guides were then subsequently modified prior to each interview with annotations suggesting specific aspects of an organisation's practice, relationships and broader discourse discovered in prior documentary research for discussion in greater detail. Details of specific projects, products or research orientations prominent in the organisation's public reporting were included as bullet points and notes in the margins of the guide for discussion. The length of annotations varied from interview to interview, in part depending upon the range of documentary resources available in the public domain, although across the project there was a tendency towards more annotation for latter interviews. This likely reflected the increasing awareness of the researcher of those aspects of organisational literature of greatest relevance to the HFC community, which allowed for the better framing of interview questions and prompts. Occasionally quotations from organisational texts were also included in instances where clarification was required on a particular logic or aspect of an organisation's contextual narrative. Routes into discussion of these subtopics were also identified and noted; usually taking the form of "tell me about X"; or "how did you become involved in Y"? In cases where it was known a participant occupied multiple roles in relation to HFCs, either through numerous relationships within a single organisation, or across multiple organisations as part of a wider career portfolio, these were also noted as potential discussion points.

Interviewing in Practice

In taking the a deliberative or active approach, interviews aimed to leave open as many potential points of identification as possible for the participant, while at the same time working through a series of topical prompts to facilitate discussion and elicit data. This required a balance in interview technique between a relaxed and open style of questioning and more active interventions designed to move discussion along; open new channels of discussion; or gain clarification on a particular construction or interpretive process. This is not to say topic guides always worked as planned, rather interviewing was a process of continuous adaptation and improvisation. Often participants raised specific practices or relationships prior to the interview reaching that point in the topic guide. In many ways such early arrivals were valuable as indicators of the interpretive links actors drew within their own organisational contexts, and as confirmations of early insights as to the relevance of a particular practice gleaned from documentary research. Such detours did however necessitate an ongoing process of interpretation and adjustment in the conduct of the interview; juggling between allowing participants the reign to introduce new ideas or unanticipated linkages into the conversation, while remaining alert to the range of discourses in play and seeking clarification and expansion where necessary. This process is at times visible in the presentation of quotes in the research findings where, due to the flexible fluid nature of interview discussions, it was necessary to provide additional contextual information from elsewhere in the interview.

In other areas the topic guide led to more productive surprises. In particular in early interviews topics of organisational context and external relationships often collapsed into one another far earlier than had been anticipated. This led to the identification of collaboration as a key form of organisational practice in and of itself. In several cases participants would speak of 'we' not only in relation to their immediate context but also to collaborative consortia and projects to which they were a party. This discussion emerged initially in interviews with academics, but as the research proceeded it became clear collaboration played a far more central role in the ways industrial and governmental actors

conceived of their activities in relation to HFC technologies. Combined with similar findings from early documentary research, this collapsing of categories precipitated the refinement of the study's case units to organisations participating in partnership activities. Moreover given the centrality accorded to collaboration by many participants, questions in this area tended to take up a significantly larger portion of the overall interview than other topics within the guide.

Conversely, the section of the topic guide headed "narratives of fuel cells" proved more difficult to access. In some interviews, narrative questions regarding how the participant came to be in their role incited clear statements of normative or ideological position. More often than not however, the end of the interview was reached with the interviewer forced to ask more direct questions; "do you have a vision for the hydrogen economy?" - "what is it"? This approach was less than ideal, seeming to jar with the flow and tone of interview conversations by inserting a new construct to the discussion that felt out of context with the broader structure of the interview discussion. At times the researcher felt compelled to apologise for the shift in tone of discussion to the somewhat 'naff' question, and was occasionally asked to further define the question. Indeed the most telling responses to these questions were when participants responded in the negative, offering a lengthy rationale for their position. It was in these sections, or the explanation of a particular organisation practice that the most valuable data on discourse tended appear, tightly bound up in participant's understandings of their own organisational context, institutional position and strategy relating to them.

The insight that cases of disagreement contributed invaluable data also found resonance in some interviews more deliberative lines of questioning. Offering potential points of contestation for discussion was often met with displays of approval; smiles; nods of the head; and clauses such as 'good question...' or 'hmm, interesting...', indicated areas where the researcher had identified points

of interpretive uncertainty or contention within broader constructions of the HFC community and its practices. Such responses were helpful as indicators of whether questioning was on track, or conversely where interviews were straying beyond the contexts relevant to the actor in question or the interpretive frames with which they were familiar. In latter interviews in particular the use of clarifying questions was also of great value, providing opportunity to gain informant feedback on formative analytic insights and interpretations of their narratives and interpretive processes (Schwartz-Shea, 2006).

As an additional check on researcher interpretation, following interviews, verbatim transcripts were produced, along with short summaries of each interview containing those points and insights the researcher had taken to be key in participant accounts. Participants were initially provided with summaries, accompanied by invitations to request a full transcript, submit comments or clarifications either by telephone or in writing by email. The rationale for adopting the summary approach to informant feedback was two-fold. In the first instance it was anticipated that busy participants may lack both the time and inclination to review an entire transcript. Secondly, by abbreviating summaries to only those key points the researcher took to be crucial to analysis, it was hoped obvious interpretive errors, omissions, or miss-readings of context would be rendered immediately obvious to participants who would then be free to offer clarification. Generally such communications were met with brief and courteous replies but little in the way of comment, a development that was unsurprising given the busy professional lives of participants and the initial difficulties many of them experienced in timetabling a date for interviews. However in a minority of cases some significant contributions were gained from this correspondence, particularly in relation to imprecise interpretations of commercial language within the community which served to further clarify and refine analysis. That being said given the limited feedback generated from the process, it was the deliberative approach to interviewing that provided the more effective means of ensuring the

interview accounts generated remained grounded in the interpretive contexts inhabited by the actors participating.

This is not to say each and every interview was entirely successful in generating rich and detailed co-produced accounts. There was a small minority of instances in which participants seemed rushed or disinterested in the interview process or in which conversation remained stilted. These cases tended to correspond to those in which participants had initially appeared sceptical of the time available to participate in the study, and had requested a shorter interview period or telephone interview as opposed to the format initially requested in recruitment letters. The most significant of these difficulties arose in one interview in which poor choice in the phrasing of a deliberative question combined with a bad telephone line to significantly alienate a participant. While the question itself was not intended to be insulting or value laden, this was the inference the participant drew and the tone of the conversation became stilted despite the researchers' best efforts to apologise. The interview culminated with the participant withdrawing consent for the use of quotations in research reporting. While the ethicality of this approach and the implications for the broader study will be discussed in the next section, here it is simply worth noting that in many respects such issues resemble the nature of conversational discussion itself.

Given the hermeneutic uncertainty in any discussion, wherein interlocutors are always interpreting each-other, never gaining direct access to some essential concept of 'true intentions' (Kvale, 1996; Gubrium & James, 2003); it is unsurprising not every conversation was identically deep, active and engaging. This does not mean such stilted accounts should be ignored. Where interviews were more stilted; this did not negate their value as part of a broader field of documents and organisational interviews through which a range of emblematic positions were identified. Indeed particular points

of contention or awkwardness yielded some useful analytic gains, albeit producing less data for subsequent analysis. While we cannot know what may have come from this small number of interviews had conversation been longer and more fluid, there is little reason to suspect that such cases undermined the integrity of the overall data available. As with refusals to participate and unquotable interviews there was no case of emblematic variation identified that was dependent on only one interview. Rather interviews and documents drawn from multiple case organisations served to elucidate this field of emblematic variation. To the extent that those more stilted interviews were notable in their divergence from others, suggests that overall the interview process was broadly successful in generating contextualised co-constructed accounts of organisations involvement in the overarching case of the HFC community.

IV. Process & Ethics

The ethical position adopted in this thesis takes its lead from accounts prioritising deliberation and the production of contextually bounded rational case knowledge as the core goals of social scientific research (Curaco, 2012; Flyvbjerg, 2001). As such, attention has been given in the above methodology to facilitating deliberation within interviews and treating participants as interlocutors more than capable of outlining their own position and responding to potentially critical questioning. In adopting this approach the aim was not to overwhelm the participant with a barrage of critical questioning, but to find a situational balance between a comfortable, participant-led account of their own practice, and a more robust negotiation of how and why that practice has come to be. The ethical aim within interviews was thus to prevent the domination of interview discussion by either the freely speaking knowledgeable participant, or the overly aggressive and combative interviewer. In this sense interviews strived to reach a deliberative middle ground; 'the mean relative to us' (Thuesen, 2011, p. 614). While the researcher retains a privileged role in the analysis of interviews and other texts, this analysis remains duty bound to reflect the range of orientations and logics present in the original data, avoiding where possible the urge to reduce complexity or collapse

categories. In particular effort has been given to recover and give prominence to implicit logics and articulations not widely held within the HFC community, but which nevertheless may constitute under-examined alternate possibilities for the development of the technology. This deliberative position has not however precluded a need to engage with more procedural elements of research ethics and their concerns with issues of participant recruitment; informed consent; data handling and storage. What follows below is a brief discussion of this engagement, the courses of action and procedures adopted and a more reflexive discussion the unresolved tensions arising in the course of the study.

In the first instance it is worth briefly summarising the procedural account of interview ethics in which the interviewer makes an approach in writing outlining briefly the purpose of the research, inviting participation and explaining why the prospective participants involvement is desired. Subject to a positive response, interviews are preceded by a reiteration of these key points and explanation of; the right to withdraw; confidentiality; anonymity and data storage; and a frank discussion of any potentialities for participant identification. The culmination of this process tends to be marked with the issuing of a consent form to be signed by both parties (Bryman, 2004; ESRC, 2010; SRA, 2003). The key pillars to this approach; informed consent and the right to withdraw were central elements of negotiation with Birmingham's ethics committee prior to entering the field.

However in the course of the fieldwork itself some deficiencies in this approach became clear. In the first instance, while there is a reasonable amount of 'how to' guidance on the writing of recruitment letters, relatively little is said in the procedural literature on making first contact with interview participants. In particular during the process of becoming acclimatised to the HFC community, first contact was made with a number of interview participants through informal conversations at public

lectures and conferences. In one or two such cases, on hearing of the project my interlocutor offered to be interviewed. In other instances the content of a presentation or details emerging from discussion made it clear an individual would be a valuable contributor to the research and a verbal request was made in person, exchanging business cards with a view to providing a written introduction letter. It could be argued that as an 'outsider' to the HFC community with little benefit to offer in terms of skills or knowledge, the benefits from these interactions were somewhat one sided. More broadly one can imagine circumstances in which making such informal approaches in a public setting may be inappropriate, and the history of ethnographic and social research is littered with instances of ethically dubious modes of informal and covert data collection (Punch, 1986). In this instance however, such introductions were not part of some covert observational branch of the research, no data was collected and no formal commitments were sought prior to the sending of recruitment letters. Informal conversations took place within a space dedicated to professional networking in which those approached were actively making themselves available to new professional contacts. In this instance making a brief personal introduction seemed not only appropriate, but more ethically justifiable than the 'cold calling' approach signed off by Birmingham's ethics committee. Indeed it is difficult to see how such approaches may have been described to an ethics committee prior to conducting research, this route to meeting participants had not been anticipated until the researcher found themselves doing it. Conversely, had procedural ethics been followed to the letter with the immediate production of recruitment letters and consent forms, without continuing discussion or allowing new found contacts to take their leave; this would have taken up additional time from the networking sessions and constituted unusual, bordering on presumptuous behaviour.

When contact was not initiated via chance personal encounters, organisations were approached directly. In many cases relevant staff email addresses were available on organisational websites and

where this was not the case initial enquiries were directed to the standard email address for general enquiries asking for the person responsible for a given area of organisational practice. When communicating with intermediaries, the researcher held back from sending official recruitment letters until put in touch with the member of staff most appropriate for interview in order to preserve confidentiality of participants as far as possible. Introductory emails were thus phrased as enquiries from a research student interested in an aspect of the organisations operations. Once in touch with the relevant staff member a request was made by email, briefly outlining the reason for the approach. Further details and the offer of additional explanation by telephone or email correspondence were contained in the official recruitment letter (a template of which can be found in Appendix 2, p.256). Letters were supplied as attachments and referred to in the body of introductory emails. This standard template contained indication of the purpose of the study as examining the community emerging around HFC technologies in the UK; the length of interviews (45-90 minutes); the conversational format to be adopted, as well as details of the researcher's institutional affiliations. Whilst conforming to procedural notions of transparency and informed consent, this introduction was also of value in setting the stage for subsequent interview conversations, establishing the broad parameters of conversation and positioning participants as knowledgeable informants.

Given the range of participants to be interviewed the template recruitment letter contained an introductory paragraph specific to the participant providing further explanation of why they had been approached and providing an indication of the types of issues to be discussed. Arranging dates for interviews and further clarifications were dealt with in follow up correspondence and phone calls during which efforts were made to ensure participants had read and understood the implications of participation. In some cases participants sought clarification of confidentiality and anonymity procedures, whilst in others they simply wanted indication of the sorts of questions to be asked. This

latter query initially caused some difficulty, somewhat contradicting the unstructured, conversational format intended for interviews. In such instances the task became one of explaining the research approach and desire for flexibility in asking follow up questions. The strategy alighted upon in conversation with these participants was one whereby they were sent a list of indicative topics and questions in advance of interviews, with the disclaimer that follow up questions would be asked and participants would be free to withdraw or decline to answer any question on the day if they so wished. Initially there was some concern such additional information may lead to participants over-preparing for the interview; arriving armed with reams of documentation and fully fluent in official discourses already gleaned from textual research, this did not prove to be the case in practice. Rather the indicative lists seemed to function simply as reassurance to participants that they were qualified to speak to the topics of interest.

Negotiating Consent

Interviews themselves were conducted at the time and location of participants choosing, in practice this was almost always at their place of work either in an office or a room booked specifically for the purpose. The only exceptions to this were a number of 30 minute telephone interviews and one participant wishing to visit Birmingham's DTC for whom a tour of the university labs was arranged. In this last instance, a room was booked in Birmingham's School of Chemical Engineering for the purpose of the interview. Short telephone interviews had not been anticipated prior to beginning of the study and were conducted on the request of participants themselves. Whilst the researcher was initially wary of gaining lower quality data over telephone interviews, initial approaches had emphasised flexibility of interview duration and not specified any particular media through which interviews should be conducted. Given this it was felt best to agree to whatever medium was most convenient for participants who would be giving up their time for the study. As noted above, in practice the experience of telephone interviewing was mixed; in several cases the researcher found it more difficult to develop rapport with participants (see pp.107-108 for discussion), in part due to the

constraints of the medium and short timeframe available for conversation. This is not to say all telephone interviews experienced these issues however; others produced rich detailed responses, and it is possible that in several cases difficulty establishing rapport would also have been experienced face to face.

On arrival at interviews (or via email in advance in the case of phone interviews), the initial exchange of pleasantries was followed by the administering of a consent form. A full copy of the form used can be found in Appendix 5 (p.261), but in summary it contained a brief reiteration of the purpose of the study; data storage; the format and length of the interview. Prior to fieldwork it was decided that it was important to gather details on specific types of organisation and practice that, given the size of the UK HFC community, could lead to the identification of participants. As such it was decided participants could only honestly be offered confidentiality rather than anonymity. A section of the consent form was thus dedicated to explaining to participants that quotes from interviews would appear in the public domain under pseudonyms and vague job descriptions that could potentially leave them identifiable to others in the community. The design of the form was subject to some discussion with Birmingham's Ethics Committee. Initially it was felt that as individuals occupying considerable positions of authority as scientists, business persons and civil servants, participants should only be offered limited rights to edit their data following interviews. Thus while introductory letters and consent forms made it clear participants would be able to withdraw at any time during interviews, following interviews participants would not have the right to edit transcripts. Rather participants were to receive summaries and have the right to request transcripts on which they could offer clarifications, with final editing rights remaining with the researcher. This being the case the Committee felt participants should be given the right to opt out of quotation under a pseudonym and a tick box was subsequently added to the consent form, which was offered to participants both prior to and after the interview proper.

In practice the final tick box proved to be something of a double edged sword, in two cases its existence gave confidence to participate in the study to an industrial representative and a civil servant who otherwise would not have participated. Whilst their input could not be referred to directly, their insights were invaluable as a check on researcher interpretations of documents relating to their organisations. In two other cases however, the existence of these boxes prompted participants to opt out of quotation at the last minute, despite prior discussions in which they had indicated they were happy to be quoted. While frustrating, the rationale for these two opt outs was reasonable. The first of these was the telephone respondent who had inadvertently alienated in the course of questioning. While the passage in which this alienation took place would have provided some valuable insight into what particular actors in the HFC community deem to be out of bounds in terms of acceptable behaviour, it is understandable the speaker in question would not wish to see the exchange appear in print- even under a pseudonym. In the second case, the researcher could see nothing particularly contentious in the interview transcript warranting an opt-out. Rather it seemed to be a response to a last minute sense of caution- possibly triggered by sight of the box itself. In this case we can be content that for whatever reason the box served its purpose in alleviating anxiety over interview participation, leaving the field, as far as possible, clear of any subsequent unease or dissatisfaction from participation in social research.

Reflecting on the issuance of recruitment letters and consent forms more broadly, there was a distinct impression in many cases that the officious tone of the documents was at odds with participants' own values of collegiality. Many would have been happy to be interviewed with no ethical assurances and for some the suggestion they required protection from a PhD researcher seemed faintly ridiculous. This is not to say participants were irritated by this approach, rather the plethora of documentation and assurances was accepted with ironic shrugs and sighs that one

associates with other forms of auditing and institutional protections inhibiting social interaction. In some cases participants took a verbal run through of the document to be accurate and signed without reading. In many cases a contextually informed ethics prepared to adapt to the conventions of the field and the stated wishes of participants was more valuable in negotiating an appropriate interview setting. However, the existence of a more structured form did at least ensure a space within this informal complex to highlight some of the risks attendant to confidentiality in the research process, and mechanisms to alleviate any anxieties participants may have had. In instances where such anxieties were displayed, and in the case of the unfortunate telephone interview, the procedural framework proved robust in ensuring any anxieties or concerns on the part of participants could be dealt with.

Performing Informing

It is worth noting here the inherent tension between the ontological position implicit in the procedural notion of informed consent, and the interpretivist position outlined earlier. If we are to reject any notion of direct access to 'true meanings' beyond situated interpretation, the same would apply to the communication of a study's goals and procedures. There are always a range of possible interpretations and purposes social research data could be put to. Also discussed above, the symbolic interactionist insight that there is no guarantee that intentions can be accurately encoded and decoded can never be fully overcome, rather we are reliant on the construction of negotiated meanings adequate to the understanding of both parties (Foddy, 1993; Silverman, 2001). As such, for Punch (1986), some level of unintended deception is inevitable in gaining access to any field. Given this position, we are left with a rather more limited notion of informed consent in which it becomes the duty of the researcher to communicate as transparently as possible what participation is likely to involve; its potential risks; the purposes of the interview and envisaged uses for any data produced. In the case of what participation entails and potential risks, these were both relatively easily explained. For the former, the task was describing relatively well-known concepts of time and

interviewing, the latter a genre of activity familiar to relatively informed citizens living in what has been termed 'interview society' (Gubrium & James, 2003). Explaining the risks was also relatively straightforward in the sense of highlighting a generalised uncertainty around the possibility of participants being identified; it was left to participants as experts in their field to judge for themselves the potential consequences. When it came to explaining the purpose of the study and use of data however, the difficulty of arriving at a jointly held understanding of a study's significance becomes more challenging. For the BSA the responsibility for the researcher is to;

'explain as fully as possible, and in terms meaningful to participants, what the research is about, who is undertaking and financing it, why it is being undertaken and how it is to be disseminated'. (BSA, 2004, p. 3)

That we should communicate who is funding and undertaking research in instances such as this is not in dispute here. However there is a risk that in adopting the language of the participant; speaking to their concepts and categories, the researcher overplays the relevance and usefulness of their work to the communities they study. This latter point proved a challenge in writing recruitment letters and providing verbal introductions to consent forms. While the standard text in both referred generally to research into the HFC community, its communication and practices, the amendable section of the recruitment letter template and verbal introductions provided an opportunity to communicate more specifically what the research was about and hoped to achieve. In articulating these introductions the researcher became increasingly aware that in attempting to speak in terms meaningful to participants, they may have generated expectations and anticipations of the research beyond its central purpose. In particular, during several early interviews with participants from industrial organisations, the research was phrased as being interested in the commercialisation of HFC technologies. Although this was intended to communicate commercialisation as an object of interest, latter reflections on transcripts suggested that some participants took this to mean the research sought to aid commercialisation.

While this realisation was itself informative, it raises uncomfortable questions about the basis on which consent was being sought and offered. Were one to make explicit all details of ontological inclination, epistemological position and theoretical constructs informing a research project; consent forms would run to the size of a thesis chapter. Some form of simplification is always necessary and in the absence of field experience and the contextualised knowledge it brings, developing introductions is necessarily an uncertain process. Once it was realised a particular form of introduction was problematic it was possible to shift to more neutral language aiming to avoid confusion, but this reflected knowledge gained from early interviews. Given the success of providing indicative topics and questions to participants who requested them, were the study to be repeated it would be tempting to provide these as standard. This would at least provide a clearer indication of the direction of interviews and the research more broadly, checking assumptions before they were made, but there is no guarantee the problem would be averted entirely. To the extent the research was committed to providing outputs to the HFC community, presenting at conferences and to the researchers own HFC research centre at Birmingham; the research has at least sought to feed its findings back into the HFC community. We may simply have to accept a degree of mutual misrecognition as attendant to the early stages research into a new community, and hope that the inconvenience caused by unintentional deceptions is outweighed by the value of the knowledge produced.

V. Summary

This chapter has sought to outline the means by which data was collected on various case organisations within the HFC community. The beginning of the chapter outlined the selection of documentary and interview methodologies as complementary approaches that enabled examination of both the formalised constructions of the HFC community and its practices, together with a more reflexive, interactive examination of the contextualised interpretive processes and logics that make such constructions possible. Selected on the basis of their capacity to shed light on the emblematic

interpretive variations within the overarching HFC community, organisations were identified through a process of documentary research which served to give an overview of the broader inter-organisational context in which they were situated prior to making initial approaches for interview. In this sense documents performed two roles within the study. In the first instance early literal readings provided factual information on the range of organisations and institutions present in the HFC community, from which case identification could begin. In the second they were read in a more interpretive fashion as crystallisations of organisational position, providing indicators of the varied ways in which organisations publicly constructed their identities and strategies in relation to the broader HFC community. In so doing documents provided initial indicators of the types of emblematic variation that case interviews hoped to flesh out in further detail. Even in the instances where case organisations were identified via snowball referral from past interviewees, documentary research served to confirm the case was of interest and provide background detail before approaches for interview were made. It was only through this process that it was possible for the researcher to be confident that the broad range of emblematic variation within the HFC community had been covered in case interviews.

Interviews on the other hand, offered a means of examining instances of emblematic variation in greater depth, providing an interactive fora through which the logics and interpretive processes guiding organisational strategy could be examined in detail. While structured to the extent that they allowed the researcher to home in on particular topics of interest to the study, interviews provided space for participants to identify those local contextual factors and institutional logics that gave meaning their organisational strategies and positions shown in more official documentation. This does not mean that interviews sought out hidden meanings; ulterior motives, or some form of subconscious intentions of organisational actors. Rather through a reflexive process of co-construction (Holstein & Gubrium, 1995; Silverman, 2001), they allowed the researcher and

participant to make explicit some of the logics guiding particular organisational or partnership activities in ways that were mutually comprehensible to both parties. Although interpretivist-constructivist research must always remain sceptical of its capacity to identically reflect the meaningful interpretations of others (Yanow, 2007), interviews and participant feedback procedures provided opportunities for member checking, both in terms of clarifying the accuracy of co-constructed understandings within interviews; and in subjecting researcher interpretations of the broader HFC community to critique from practically experienced community members (Flyvbjerg, 2001; Schwartz-Shea, 2006). It was only through recourse to the deeper, contextualised knowledge of interview participants that it became possible to provide a rich, deep account of the HFC community that captured the nuances in variation between emblematic actor types.

In turning to research ethics, where appropriate the chapter has made reference to the procedures deployed for ensuring participant confidentiality, data protection and participants' rights of withdrawal. More detail on these can be found in Appendixes 4 & 5, however the primary purpose of the above discussion was to highlight some of the key points at which a procedural approach to research ethics was found lacking. More specifically, the above discussion focused on some of the uncertainties around proper researcher conduct when encountering potential participants in contexts outside of the formal data collection process, and some of difficulties inherent to communicating research intentions prior to the conduct of interviews. Encountering these issues 'in the field' as it were, the researcher felt somewhat underprepared by the committee based ethical approval process provided via the host university. In falling back on context based judgements, the researcher remains confident that their responses to these issues under the circumstances were appropriate, and that approval supplied by the committee remains valid. Notwithstanding this however, the procedures inculcated in the study in the form of consent, participant feedback and

withdrawal mechanisms did at the very least ensure that any hesitations participants may have experienced within the process could be quickly dealt with and reassurances offered.

Finally it should be noted here that while the researcher does not claim perfection in the management of every ethical dilemma, nor in representativeness of the sample of documents and interviews collected; we can be confident that the procedures outlined in this chapter have ensured that the research meets the standards of credibility, rigor and ethicality expected of contemporary interpretive research. The combined documentary and interview based approach conducted ensured no statement in the researches subsequent analysis was dependent on a single source or interpretation but was evidenced in a range of documentary constructions and participant interpretations. While the participant feedback process did not generate the levels of engagement initially hoped for, the deliberative interview process itself proved highly successful as a means of member checking researcher intuition. Engaged responses to interview questions and the occasional correction, or in some cases participant queries as to the premise of a question, proved a powerful means of ensuring discussion remained grounded in the practical experiences and interpretive contexts of participants themselves.

6. ANALYSIS

I. Analytic Process

Upon being confronted with a mass of documentary and interview accounts of the HFC community, four tasks stood out at the start of the analytic process. The first was one of gaining familiarity with the data at hand, a task achieved via a combination of repeated listening to and transcription of interview recordings, reading and re-reading policy documents. Beginning alongside the conduct of fieldwork, it was possible at this stage to develop some initial ideas of key themes emerging from the data. During this process three elements began to emerge as the basic units of analysis through which it became possible to make sense of the emblematic variation within the data at hand;

- 1) a cast of actors which while heterogeneous; nevertheless corresponded to five categories with distinct orientations and roles within HFC governance;
- 2) a set of institutional practices and metaphors which established the basic practices and categories through which HFC governance is interpreted and enacted, and finally;
- 3) a set of meaningful constructions of strategy through which differentially positioned actors have sought to engage with HFC governance practices.

In practice these three units emerged in unison, with the analyst initially only partially aware of the distinctness of each. The trifold distinction presented here and reflected later in the thesis' presentation of findings rather reflects a process of conceptual tidying required to communicate as clearly as possible the research process undertaken. In making this separation, the analysis owes a debt to the interpretive policy analysis of Dvora Yanow (2000; 2007), whose interpretive concepts of narrative, metaphor and categorisation provided the eventual basis for presenting findings. Oriented towards the development and implementation of a single policy however, Yanow's account has been adapted here to pay closer attention to institutionally and discursively mediated strategic practices which are more commonly the focus of more actor-centred constructivist approaches (Hay, 2011; Saurugger, 2013). The following sections correspond broadly to three parallel analytic tasks. The first task aimed to identify the varieties of agency and interpretive position present within the HFC

community by examining narratives of organisational history and context, focussing on the contextualised narratives through which actors interpreted their interests. The second task involved examination of the intersubjectively recognised institutions of the HFC community, including the key institutional actors; practices and metaphors which shape the construction of HFC innovation governance. Finally those institutions were examined from the strategic perspective of different actors within the HFC community, with a view to identifying the categories and power dynamics which shape innovation governance in practice.

The three analytic tracks outlined in this chapter were not conducted in isolation but rather via an iterative process of analysis, writing and cross validation, through which each track informed and refined the others. This is not to say the analysis sought to present an abbreviated replica of all data collected, or to triangulate between accounts in order to describe some underlying reality to the actors, practices and meanings encountered. Rather we should recall our earlier discussion of case study research (Chapter 4, pp.70-74) as a means of providing an account of the community under study which seeks to preserve the emblematic differences and divergences within it while providing a simplifying narrative logic to render that community intelligible. The articulatory task thus required the combination of prior insights drawn from practical experience of and participation in the discourse of the HFC community, with theoretical knowledge and expertise of the analyst. In analysing across three different tracks, moving iteratively between each and the broader literature around network governance and sociotechnical transitions, it gradually became possible to make sense of the diversity of data collected during field work. Individual narratives of position became fleshed out in examination of intersubjectively recognised practices and through examination of the difference in meanings subsets of the community attached to them. This was a highly iterative process; a number of accounts were written, in particular relating to intersubjective practices and meanings. A number of articulatory attempts were made at reconciling these with the accounts and interpretations of individual actors and documents within the study. Combined with efforts made

during the interview process itself in which early analytic intuitions were crosschecked with participants, the resulting process sought to ensure at the very least categories and theoretical constructs developed could account for the interpretations and constructions made by interview participants. This is not to say every document studied or interview participant would agree with the analysis presented. Indeed given that the analysis identified multiple differentially positioned interpretive communities, the best it could hope to aim for was to translate the categories and meanings of those communities, and develop a theoretical construct; 'world making' in Yanow's (2000, pp. 86-92) terminology capable of elucidating and accounting for that difference.

II. Actor Narratives

Early analysis began during field work without a full picture of the data. Initially analysis sought to make sense of each account in terms of its situational specificity and the individual narratives or storylines through which organisations made sense of their work with HFCs and, by extension, innovation governance more broadly. Such narratives resembled the description offered by Yanow (2000, pp. 58-61), speaking to the sense-making processes actors use to give meaning to their work and position in relation to policy making or delivery. This was not narrative research in the sense of traditional biographical interviewing, where life-course factors are prioritised to help understand present day experience (Squire, 2008; Shirani, et al., 2015), nor of the literary criticism inspired variety in which components of narrative structure are examined to explore how actors seek to construct relationships with other actors and artefacts (Silverman, 2001, pp. 124-126). Rather analysis took inspiration from argumentation theory and discourse analysis, looking to the contextual premises and knowledge claims underpinning the causal stories actors deployed (Dryzek, 2005; Fairclough & Fairclough, 2012; Tellman, 2012; Van Leeuwen, 2007). In so doing it was able to draw on narratives of organisational history and experience presented in interviews and the broader rationales given in press releases; corporate reporting; policy briefings and mission statements. Analysis of these causal narratives allowed the researcher to unpack how actors interpreted their

interests, and sought to explain and legitimise their participation in the HFC community as; bankable investment propositions; deliverers of reliable technologies; impactful researchers; or responsive governance agencies. In this sense examining narratives helped understand how the wide group of organisational actors found by field work framed their involvement in HFC innovation governance.

The second move made at this stage in the analysis meant returning to the innovation studies literature; especially concepts of niche innovators and regime incumbents (Geels, 2002; Rip & Kemp, 1998; Winskel & Radcliffe, 2014); and practice theoretical accounts of socio-technical systems which emphasise the role of competencies, context and meaning in the reproduction and transformation of regimes of practice (Shove, et al., 2012). While this literature did not fully account for the variety of actors and differences speaking in the texts collected, it helped orient the analysis to the narratives of organisational expertise and market position present within the data.

This return to the innovation literature happened alongside the field work, following the lead different actors gave to established reputation or relations with regime and niche actors. This somewhat eclectic mix of analytic concepts was neither the product of a preconceived conceptual framework nor an uniformed reading emerging naturally from the texts examined. Rather it reflects a gradual honing in on context; competence and meaning as key components in the individual narratives of HFC community members, expressed in their framings of potential uses for their technologies; claims to expert knowledge and skill; identifications of market opportunities and risks. More specifically they emerged from the intuition, gleaned from cross examination between narratives and the innovation studies literature, that particular narrative framings of context; competence and meaning, corresponded to archetypal positions inside existing energy and transport regimes.

By treating competence; context and meaning as dimensions of a particular kind of actor narrative it became possible to identify three (later refined to five) ideal types of actors adopting common means of interpreting and constructing their space for strategic action within the HFC community. Of these dimensions, the first ‘competencies’ spoke to the combination of expertise, skill and tacit knowledge (cf. Shove, et al., 2012, pp.21-26) invoked by actors to explain and claim authority for their involvement in HFC innovation, not in the sense of specific skills and abilities, but rather the more generic attributes through which they felt capable of contributing to the HFC community (Van Leeuwen, 2007; Tellman, 2012). The second dimension, ‘context,’ referred to the aspects of wider sociotechnical regimes and landscapes actors took to be essential to the emergence of HFC innovation as a practice (cf. Shove, et al., 2012, pp.21-26). Such invocations of context were examined for their function in actor interpretations of interest in HFC innovation governance, alongside their role as premises in broader constructions of why their participation in such activities was a desirable or legitimate activity (Fairclough & Fairclough, 2012; Van Leeuwen, 2007; Yanow, 2000). The final dimension; ‘meanings’ refers to how particular actor types interpreted and framed their interests in providing solutions to particular techno-scientific problematisations (cf. Shove, et al., 2012, pp.21-26); constructed in light of their competencies and contexts; often using the vernacular of ‘opportunities’ and ‘risks’. The latter dimension did not merely focus on actor interpretations, it also sought to encompass the meaningful strategies of actors positioning themselves within the broader HFC community.

Table 4: Typological Dimensions

Dimensions			
Type:	Competency:	Context:	Meaning:
	<i>Expertise, skills, tacit knowledge</i>	<i>Relevant socio-technical regimes and landscapes</i>	<i>Interpretations of opportunities and threats.</i>

In establishing these dimensions and the actor categories derived from them (see p.159), validity was established in two ways. Firstly across interviews, each account was examined with a view to establishing relative homogeneity within each category. This is not to say actor interpretations of each dimension had to be identical, but rather that they fit within the broad band of dimensional descriptors demonstrated. For example in one actor type a collection of meaning framings around 'market opportunity' served to define the type, regardless of the specificity of the particular market or HFC technology individual actors corresponding to it might be focussed on.

While the types established were 'ideal' in the sense they spoke to archetypal theoretical constructs, this process of cross comparison led to a gradual expansion from three to five types, to account for notable differences within initial broad categories for 'incumbent' and 'pre-commercial' actors. Secondly the validity of each categorical construct was itself tested to show a meaningful relationship between the dimensions identified within it (Kluge, 2000). Multiple interview and documentary extracts were examined for each category to check that the interpretations of context and competency attributed to them in analysis adequately explained the constructions of meaning found within them. While other analysts may well have found a different basis for creating types or teasing out more categories; we can be confident that at the very least the constructs established here meet these criteria of homogeneity and meaningful interrelation.

III. Institutional Analysis: Actors, Metaphors and Categories

The second analytic track adopted concentrated on the institutions identified by actors across the HFC community as influential in innovation governance. Such institutions split into two groups. Firstly there are institutions, often government departments and public bodies which can be considered agents. They are guided by institutional rules and logics with the capacity to communicate and interact with others displaying varying degrees of discretion in the actions they take. Revealed during

the preliminary literature reviews and sampling processes, several such institutional actors were taken as being relevant to the study and worthy of recruitment for interview.. Secondly there are institutions in the sense of widely cited metaphors, categories and organised practices which displayed high levels of intersubjective recognition, and featured consistently across texts collected. The second analytic track attempted to elucidate these inter-subjectively recognised institutions and categories. Initially institutional analysis began with texts coming from institutional actors (hereafter referred to as policy actors). These early readings yielded various themes that seemed to act as key principles in HFC innovation processes. In particular a set of relations between commerce, research and government, were consistent in constructing how HFC innovation and governance should be managed in practice

In choosing policy institutions as institutional actors, there is considerable overlap between the first and second analytic track. At first policy actors were included in the typology of actors based on competence, context and meaning discussed above. The rationale for separating these actors out and discussing them in terms of institutions was in part a product of writing up. Much of the contextual detail and meaning attached by policy actors to HFC innovation was adequately covered in the literature review sections on energy and innovation policy, and in the background provided for HFC innovation (see chapter 2; in particular Table 2, p.26). Moreover, in examining policy actor narratives it quickly became apparent that they did not identify themselves as part of the HFC community; rather they saw themselves as enacting particular policy remits and logics which included HFC technologies. Given the influence of the institutional logics and categories employed by policy actors on the broader interpretations and strategies of HFC community members, locating discussion of them within institutions made greater explanatory sense than treating them as just another category of actor. This is not to say policy actors were not subjected to the kind of narrative analysis discussed above (an early narrative analysis for a range of policy actors can be found in

Appendix 6, p.263), but rather that their accounts were more enlightening as sources of data on the metaphors and categories used to understand and enact processes of HFC innovation governance.

From the outset it was apparent that a wide variety of policy institutions undertake HFC innovation governance. While narrative analysis of these institutions' histories revealed differences in terms of the concrete aspects of innovation; climate and energy policy that different institutions emphasised as motivating their work with HFCs, these divergences did not seem explicable in terms of divergent contextual interpretations or competencies. Instead they reflected differentiated responsibilities within the context of broader national and European policies for energy and innovation. What did emerge however was a relatively consistent set of metaphors and categories which institutions deployed to conceptualise how HFC innovation should be governed in practice. While in practice the analytic process was less mechanical in distinguishing between metaphors and categories, the remainder of this section teases these out as distinct as distinct forms of analysis.

Metaphor covers a range of substitutive functions through which a referent subject or object is replaced or modified by being placed in collocation with another term to modify its meaning (Chandler, 2007). Such substitutions not only operate to frame meaning, but in equating one often novel or neutral referent to another, metaphorical substitution can appeal to a broader range of discourses and policy paradigms to legitimise particular actions as appropriate and in line with the expectations of that broader discourse (Van Leeuwen, 2007). Yanow's (1996) classic study of Israeli community centres shows how the metaphor of the centre as supermarket framed expectations and claimed legitimacy through the invocation of the modernity; variety and choice, associated with supermarkets in 1970s Israeli society. While no single metaphor was as ubiquitously employed as Yanow's Supermarket, there were broader configurations of metaphorical substitutions and modifications which, when compared side by side achieved similar operations in constructing the

governance process in terms of a definite end goal 'commercialisation'; and a particular set of means for governance actors to achieve it- 'partnership'.

In contrast categories refer to the concepts by which social and institutional relations are defined and organised. Such categories are not just descriptive or linguistic; they carry performative power in authorising particular forms of action and identity (Bourdieu & Wacquant, 1992; Yanow, 2000).

Embedded in institutional rules and structures, categories reflect pre-existing and entrenched power differentials which privilege some social actors over others in the running of institutions (Foucault, 1989; Fairclough, et al., 2003). These categorical differentiations play a key role in science and technology studies accounts of the 'boundary work' done by scientists; engineers and policy makers, specifying the forms of rationality and knowledge acceptable within science and technology governance via distinctions between expert/lay; science/politics; rational/irrational (Burchell, 2007; Liskog, 2014). As with metaphors, across texts there was no single set of categorical distinctions identically reproduced. However underlying the specific terminologies and foci of different institutions, there was a broadly shared set of categorical assumptions underpinning how policy actors interpret their responsibilities and those of the community they serve; and the expectations of HFC community actors of the space open to them in innovation governance practice.

Identification of metaphors and categories arose from examining common referent practices identified across texts. It started with text extracts referring to a singular institutional practice such as conferences; funding meetings; project consortium or public-private partnership. Statements of goals, tables and lists of organisational structures and rules were drawn from policy documents and examined for the metaphors they invoked and categorical distinctions being made. At first this process was relatively unstructured and located within the process of narrative analysis. However the analyst increasingly found themselves picking out metaphors that were accorded particular

prominence in the narratives being examined. Working across institutions, a level of recurrence emerged in the categories and metaphors encountered to the point that closer examination and elaboration was conducted in an effort to make sense of if, and how, a common set of meaningful configurations underpinned all institutional interpretations and constructions of HFC innovation.

Extracts containing a given metaphor, and close variations on it, were examined side by side with a view to identifying the kinds of actions they referred to; the relations between actors they sought to construct and the broader discourses from which they drew meaning and legitimacy. In so doing analysis went beyond the data at hand, drawing on broader theoretical literatures and understandings of context to allow a richer elaboration than would otherwise have been possible (Yanow, 2000, pp. 41-47). From this some substitutions and modifications emerged across policy institution texts linked to commercialisation; the eventual goal of HFC innovation. While commercialisation was not always used metaphorically, the term and close synonyms proved the most salient modifier of policy actors' language attached to the subject of HFC innovation.

Conversely partnership was a more difficult metaphor to pin down, at times speaking to particular organisational forms, at others used synonymously with terms such as collaboration; being 'customer focused' or part of a consortium. In each case it spoke to the need for collaboration between policy actors and others in order to deliver the goals of HFC innovation. Speaking to wider discourses of market liberalisation and new public management, it was the relative role of different policy actors and institutions that explained the variations in emphasis observed in the data.

Underpinning these metaphors were a series of categories, sometimes implicit, but often becoming explicit in institutions' rules and membership criteria defining those actors most relevant to their work. While these categories were distinct from metaphors in capturing how policy actors (and HFC community members themselves) interpreted the legitimate roles and practices allocated to actors falling within them, the relations and hierarchies found within these categorical distinctions were

informed by overarching policy metaphors of commercialisation and partnership. At broad est level, ‘industry’ (delivering commercialisation); ‘researchers’ (providing breakthrough technologies and research support); and government (partner funding the work of others and facilitating larger scale collaborations) formed the central categories recognised across the HFC community. Unlike metaphor analysis where broader contextualised knowledge was introduced from outside the data; here it was possible to elaborate distinct categories on the basis of their differentiation from one another (Yanow, 2000, pp. 48-57), and the assumed values various interview participants and policy texts projected upon them. Table 5 provides an indicative list of the overarching categories which shaped both how policy actors interpreted their core constituents in the HFC community, and from which HFC community actors interpreted and constructed their respective roles in innovation governance.

Table 5: Indicative category analysis

Category:	Industry	Research	Government
Synonyms:	Business, private sector	Universities; academia	The state; the commission (in the case of the EU)
Actors:	Private companies	Universities; government labs	Government departments
Role in HFC innovation:	Deliverer of products and systems	Producers of knowledge and know how	Facilitation and funding
Assumed interest in HFC innovation:	Profit	Objective interest/ curiosity	Environmental and economic public goods

IV. Intersubjective and Strategy Analysis

If the first two analytic tracks presented a cast of actors and an institutional architecture, the third track examined the interplay of these actors and institutions in practice, examining how actors narrated their responses to the institutional actors; categories; metaphors and practices they

encountered in HFC innovation governance . While the findings presented in Chapter 9 discuss a strategic differentiation in terms of particular varieties of governance practice (conferences; project participation; planning and fund allocation processes; evidence creation and lobbying; and partnership membership), these variations are analytic constructs seeking to capture a range of practices referred to in policy and HFC community actor texts. These constructs arose from the same gradual process of cross-comparison between texts from which actor types, metaphors and categories appeared. However, whereas tracks one and two looked to individual interpretations, track three studied the differentiations; critiques and modifications to common categories and metaphors that actors employed in describing their positions and strategies compared to others. These strategic explanations often drew upon or re-stated interpretations of context; competency and meaning, to narrate the relations underlying participation in a particular practice. Given this, track three both informed and was informed by the narrative analysis of track one. However, whereas narrative analysis sought mainly to examine the contextualised self-interpretations of particular actors, inter-subjective analysis addressed actors' narrative interpretations and constructions of others within the HFC community. In so doing, it highlighted the strategic adaptations made by individual actors and types in light of their perceived position relative to other actors and institutions.

Unlike analytic tracks one and two, track three was not characterised by a single strategy of interpretation. Instead it adopted the common interpretivist approach of question driven research, using all means available to answer the basic question; "what is going on here?" In doing so this track drew on the other analytic strands, theoretical knowledge, and more situationally specific interpretations. The aim of this strand was to examine aspects of the individual and cross-case narratives; the construction of particular practices and dynamics innovation governance; or the interpretive process deployed by different actor types in developing their strategies. These strands

stemmed from either their commonality (they were typical of multiple accounts and narratives), or because they were unusual or offer special insight into an actor or types' strategies. Sometimes judging whether these unusual instances were singular exceptions or suggestive of more commonly experienced yet unarticulated strategies was difficult to ascertain. Allusions in other interviews, pauses and hedges around particular questions, provided the confidence to speak to such exceptional statements with a reasonable expectation that the strategies and interpretations contained within them were more widely shared. Where such corroboration could not be found, and exceptionality failed to yield a particular insight into an important actor's strategy, they were excluded from further consideration. This applied both in the wider analytic task of understanding particular practices, and in the narrower task of presenting its findings. The overarching aim was to grow our understanding of the processes of HFC innovation governance in all its forms, not in the sense of a topographical map focused on institutions, but rather in terms of a complex strategic field in which the actors of the HFC community sought to pursue their interests in light of their interpretations of competence, context and meaning, and the institutional rules and metaphors which shaped and were shaped by their strategic interactions.

V. Summary

This chapter outlines in as clear a way as practical the analytic process which generated the findings discussed in the following chapters. In so doing a degree of conceptual tidying has been necessary to communicate a highly messy and contingent analytic endeavour. The three tracks outlined above were not distinct analytic endeavours but three different tools working iteratively with and upon the data. Separating them in this chapter reflects both the need to simplify and explain what was done with the data analysed. It also prefigures the presentation of research findings which variously present a narratively derived typology of actors within the HFC community (see; Chapter 7); a description of the policy actors and institutions this community took to be key to their work (Chapter

8); and a discussion of the intersubjective interpretations and strategies adopted by particular actors and actor types in navigating the HFC community (Chapter 9).

While the emphasis of each findings chapter corresponds to a particular object of analysis, each section draws insights and exemplary extracts from all of the analytic tracks. Institutional categories and metaphors demonstrate key shapers of actors' narratives of context and competence. Narratives of policy actor practices shed light on the workings of particular institutional metaphors and categories, while actor strategies are often discussed in the form of narratives or the actor categories to which they correspond. Aiming for total correspondence between each analytic track and findings chapter would be unnecessarily artificial, especially given the need to keep illustrative extracts brief. Where extracts are used in presenting findings, consideration was not given to correspondence between track and findings section, rather extracts were chosen to quickly capture and illustrate a particular facet of actor interpretation; institutional meaning construction or strategic consideration. There is however little denying a level of correspondence between the three analytic tracks outlined above, and the findings presented below. This correspondence is a result of the contingent experience of conducting field work and making sense of the data at hand, combined with the equally contingent theoretical experience and leanings of the researcher.

Analysis underwent numerous drafts and attempts at world making before an eventual description of the HFC community could be produced that was theoretically consistent with itself and the data it drew on. Multiple interpretations were amended or abandoned in light of outright contradiction by interview participants. In particular early anticipations of NGO involvement in the community and suspicions that divergences in discursive repertoires and priorities may have lead researchers; industrial participants and governance actors to operate at cross purposes proved unfounded. These

intuitions; guided in part guided by naive readings of early actor network theory (Callon, 1986), discourse theory (Fairclough, 2003) and interpretivist notions of meaning communities (Yanow, 2000), simply provided poor fits to the data collected. While some early interviews initially appeared 'fit-able' with these intuitions; the more data collected the less likely this became. In contrast subsequent searches of actor centred constructivist readings of institutions, governance, and innovation provided a set of theoretical concepts that were more consistent with the data at hand and offered a conceptual structure making sense of the community at hand. In particular, knowledge of actor centred constructivism provided a conceptual language of actors, institutions and strategies (cf. Hay, 2007; 2011; Saurugger, 2013) through which different aspects of the dataset could be interpreted.

There was no one Eureka moment when this framework and the analytic process came together . Rather a gradual process of interpretation and interpretive world making eventually gave rise to the correspondence between the interpretivist-constructivist analytic strategy embarked upon; the theoretical framework which made interpretation possible and the articulation of findings presented in the following chapters. It is possible, if not likely that another analyst with different theoretical competencies given the same data, could provide an alternate account of the HFC community; possibly one located in the imaginaries of 'the hydrogen economy'; 'homes of the future' or 'hydrogen mobility'. Alternatively one could examine the implicit value positions in claims to efficiency; sustainability and economic growth articulated in many of the texts studied. A host of valid interpretations are available given the data at hand, however to the best of the researchers knowledge, none provide as adequate a description and explanation of the data as it relates to HFC innovation governance as that made possible by the interpretivist-constructivist framework adopted here.

Before proceeding, it is worth noting that the analysis offered by the above approach does not claim to represent identically some essential reality to the HFC community, rather it seeks to sketch key interpretive positions within it, each of which represents an analytic construct. While this construct has sought to avoid conflating and misrepresenting the accounts collected, in the process of complexity reduction some detail has been omitted from the resultant description. Particular categories of actor; metaphor and categorisations spoken to in the analysis, represent a more variegated set of interpretations and constructions, which may well be more permeable and liable to modification than when they appear in the single snapshot presented in the period of study and moments in which texts were first uttered. Bear in mind that while the purposeful sampling framework adopted in the study explicitly sought variety and has been conceptually expanded within the subsequent analysis, it never aimed for statistical randomisation or representativeness. Given the level of corroboration found between texts in the analysis we can be reasonably confident the overall description provided is broadly representative of the community as it is perceived by the key policy actors; researchers and industrial actors involved. However when it comes to appropriately weighting the role of each within the finding the task is more difficult. In some places the roles of a particular actor or type may have been over or understated. Certainly the 'early mover firms' identified in Chapter 8 comprise a small group who, for varying reasons, lack the degrees of influence other actor types exercise in HFC innovation governance. The decision to accord them a prominent role despite their small size and numbers, was taken in part due to their prominence in the HFC community despite their small size and numbers. Similarly their divergence from the mainstream itself illustrates the interpretive and constructive processes driving HFC innovation governance. The lack of a statistically weighted way to represent the HFC community reflects a weakness in its inability to comment on how influential a given strategy or actor type may be, however also reflects the strength of the analysis' capacity to respond to the contextualised relations emphasised by actors in their strategic negotiations of innovation governance institutions.

7. THE ACTOR LANDSCAPE

I. Actors: Competencies, Contexts and Meanings

Analytically making sense of the HFC community proved challenging. At its most basic level this community could be described as encompassing actors drawn from a heterogeneous range of academic, industrial and policy making organisations. While academic scientists and engineers shared institutional contexts and rationales similar enough to warrant discussion as a single group, governance actors tended to construct their role as separate to but supportive of this community. Given this and the special institutional position governance actors occupy within the HFC community, discussion of them will be deferred to the next chapter. The following chapter therefore focuses on a somewhat narrowed community of academic and industrial actors that identify interests in HFC technologies.

Operating with a range of fuel cell types, across a range of applications, the HFC community is a multifaceted entity containing a variety of actors from academics; consultancy firms and small scale producers of HFC technologies, through to multinational corporations such as; energy utilities; industrial gas manufacturers and global automotive firms. Each organisation has its own reasons for undertaking HFC activities. For some, the technology is the primary point of identification for the organisation, for others it offers a future opportunity; risk; or an opportunity for transformational change. Within this diversity, collaborations coalesce around individual HFC applications. No single organisation has so far demonstrated a complete HFC energy system singlehandedly. We thus see automotive firms combining their efforts with industrial gas companies; fuel retailers; energy utilities and, at times; smaller producers of fuel cells and electrolyzers, in order to demonstrate functioning HFC transport systems. We see this replicated in micro-Combined Heat and Power (mCHP) and grid balancing applications where actors with expertise in different parts of the system meet to articulate and enact the whole.

Memberships of different application communities tend to form closest bonds but many organisations operate across various fuel cell types and demonstrations in each application have tended to draw in actors from others to develop full systems. Moreover, shared trade bodies like the UK Hydrogen and Fuel Cell Association (UKHFCA), conferences and professional networks promote a broader sense of mutual endeavour, making it possible to speak of a community of communities taking HFCs as its object. This is not to suggest equal commitment by all to HFC community actors. As we shall see some organisations see the technology as peripheral to their own core activities. When exploring HFCs as a peripheral activity, actors inside these organisations get drawn into the HFC community to varying extents.

This chapter cannot outline each sub community in detail, such a task is outside the thesis' scope; this chapter just tries to outline the key means through which actors of different types seek to interpret and position themselves in relation to their preferred technologies. In particular it examines the interplay between actors' competencies, contexts and meaningful interpretations of interests, finding in the process five ideal types of organisational actor;

1. Research institutes: academic institutions who can lay the clearest claim to 'objective' techno-scientific competence, and take institutional criteria for research funding and the need to generate useful social impacts as the key contextual factors and meanings at stake in their work.
2. Pre-commercial firms: private companies with significant techno-scientific capabilities in HFCs. Yet to generate net profits, such firms rely on investment and policy landscapes which view low-carbon energy as a sound proposition. Combining these readings of competences

and contexts encourages pre-commercial actors to perceive themselves as well placed to exploit emergent market opportunities.

3. **Enthusiastic Incumbents:** large multinational companies with competencies in the logistics of delivering goods and services to a range of existing mass markets. Contextually such firms believe they face unfolding landscape pressures from resource depletion; climate change; business sustainability, which pose risks to business costs; regulation and corporate reputation. Anticipating these issues, particularly in light of past oil shocks and longstanding R&D experience, these firms have established techno-scientific competencies in HFC innovation, some going back 40 years. Enthusiasts embrace HFC technologies as a valuable competitive edge and market opportunity.
4. **Cautious Incumbents:** large multinational companies with similar competencies and contextual experience to their enthusiastic counterparts but lacking in significant HFC capacity. They engage with HFC technologies to reduce technological uncertainty and managing the landscape risks they perceive.
5. **Early Movers :** small producers of niche HFC products who claim competence from their techno-scientific expertise and independence from those they perceive to be the vested interests of incumbent energy and transport regimes. Adopting a more radical and constrained view of the environmental and resource contexts such regimes face, early movers see themselves as disruptive niche innovators; ready to meet the needs of a more sustainable future.

The above typology introduces the range of strategic positions open to HFC community members. “Strategic positions” here serves to indicate both actors’ understanding of their capabilities and options in the HFC community, and the positions they adopt in more public constructions of organisational identity and purpose. There may not be a clear distinction between internal interpretations and external constructions, participants themselves made no such distinctions, and such a view finds little support in the extended literature on qualitative social research (Holstein & Gubrium, 1995; Kvale, 1996). Rather interpretation and construction should be seen as mutually constituted via an ongoing process of structuration in which interpretations of capability and context are constructed through the practice organisational formation and strategizing (Giddens, 1991). The remainder of this chapter cannot illustrate every conceivable typological position or combination in detail. Instead it portrays how the dimensions within the above typology function to produce particular interpretations and constructions of strategic position and meaningful interests.

II. Research Institutes

For research institutes, HFCs are inextricably bound to questions relating to the future of UK and international energy imaginaries, wherein the technology offers potential solutions to issues of CO₂ reduction; energy security; and broader questions of economic competitiveness and growth. These interpretations of context are not neutral, they draw on research funder priorities. One older research institute professor gave a detailed history of oil shocks and earlier climate change concerns stimulating periodic rises in HFC funding and academic research. Others mentioned ‘funding fads’ for various technologies, and areas of public policy concern in transport, grid balancing and the decarbonisation of heat, as central motivating factors behind particular research programmes. Research institutes and their academics are not blind followers of funding priorities; rather in interviews and documents such priorities were interpreted as indicators of the broader public benefits techno-scientific research can provide.

Engineering and Physical Science Research Council (EPSRC) funding criteria emphasising energy as a core thematic area and expectations of industrial impact- the notion that techno-scientific research should contribute to economic growth (EPSRC, 2010; RCUK Energy Programme, 2011; SUPERGEN, 2010), provided key frames through which research institute actors interpreted the contexts in which they are placed. Such meaningful interpretations formed key organising principles around which research institutes built their broader strategies. The following extract from the first two organisational aims of EPSRC's H₂FC Supergen Hub are exemplary here (Stockford, et al., 2013);

“1. To demonstrate and enhance the role of UK HFC research and to link this to the wider landscape internationally. This will cover the issue of managing increased penetration of intermittent renewables, ensuring future secure and affordable energy supplies and low carbon transport and heating systems.

2. To link the academic research base with industry to ensure effective and appropriate translation of research to support wealth and job creation for UK plc.”

The quote establishes the primary aims of the Supergen Hub; a research centre based at Imperial College at the centre of a broad network of other research institutes with expertise in HFC technologies. In aiming to demonstrate and enhance the role of UK HFC research, the institute appeals directly to criteria for research quality, international excellence and energy systems impact espoused in broader EPSRC and Research Councils UK Energy Programme literatures (EPSRC, 2010; SUPERGEN, 2010; RCUK Energy Programme, 2011). The subsequent reference made to landscape issues regarding intermittent renewables; secure and affordable energy supplies; low carbon transport and heating, similarly point to the aims of broader RCUK energy programme as the key contextual factors through which the Hub interprets and legitimises its work. In claiming to address these policy issues, the Hub does not position itself as an interested actor. The contextual problems it orients towards, and the differentiation from 'industry' provided in aim 2 both operate to establish the Hub as an objective source of expertise, providing techno-scientific 'research support' to policy makers and businesses (for expansion on this point see pp.208-209).

The secondary aim, achieved through partnerships with private companies, again implies an objective interest; this time in UK wealth and job creation. The means to this goal; the 'appropriate translation of research', highlights the boundary the Hub (and the HFC community more broadly) perceives between research institutes and industrial actor types. While academics provide useful research, it is industry that is expected to deliver utility. This extract, is representative of a broader narrative in the discourse of research institutes in which the value of academic research is its commercial potential. The identification of such benefits for 'UK plc', a metaphor conflating public good with business success, underscores the shared interest of the publicly funded research institute and the private industrial firm. This logic does not originate with the Supergen Hub, it is a key by-product of the distinction governance actors make between the public sector's role in facilitating innovation and the private sector's role delivering it.

III. Pre-Commercial Firms

Pre-commercial firms often make similar claims to techno-scientific competence as research institutes. However, whereas research institutes interpret their expertise in the context of funding priorities and objectivist assumptions regarding the public good, pre-commercial firms do so in the context of markets. Nevertheless their similar positions, combined with pressures on research institutes to deliver impact drives a high degree of mobility between them. Collaborative research networks and companies 'spinning out' of research institutes is typical in the UK's pre-commercial landscape, as are informal collaborations and consultancy arrangements sometimes embedded within publicly funded projects. However it is the differential interpretation in context which allows pre-commercial firms to espouse divergent meaning for HFCs and authorise alternate strategies to realise them. Talking of the decision to spin out a pre-commercial firm from a university laboratory, this extract from an interview with a fuel cell micro-CHP manufacturer is exemplary:

‘Basically we started the business research in 2000, came out in 2001, erm the mantra was to - the energy sector was all over the financial news every single day, blackouts, big power issues, CO2 emissions, the whole environmental-energy side was ramping up, so the market was ripe.’ (Pre-Commercial Fuel cell mCHP manufacturer 1i)

Here the interviewee places HFCs as part of the wider regime and landscape of the UK energy system; increasing enthusiasm for ‘environmental-energy’ technologies and emissions reduction.

The reference to blackouts reflects a particular interpretation of energy security arising from unreliable electricity supplies; often attributed to ageing infrastructure in advanced capitalist countries. This particular reading speaks both to the salience of this issue in the period the participant refers to, but also their own specific techno-scientific competencies in fuel cell mCHP; a technology they feel could enhance the resilience of the electricity grid by offering households’ independence from centralised generation.

This said, the first and final clauses of the extract indicate that this is not the objective ‘high level’ picture that tended to be offered by research institute participants. The participant places their expertise in the energy system as stemming from ‘business research’; conducted with the explicit intention of creating a ‘spin out’ company from the participant’s former base in a research institution. What we see described here is a fundamentally different type of techno-scientific competence, geared towards commercial activity. The deployment of the term ‘ripe’ here functions to communicate the participants’ interpretation of energy markets as ready to invest in emerging secure and low-carbon technologies. Continuing their discussion, the participant begins to highlight their own expertise and institutional context in relation to the markets they have identified:

‘So in terms of trying to spin a company out into the energy area with a technology that offered something that was very unique; with a patent that had been filed at the time, with the capability of the scientists and the knowledge of the scientists around it, a lot of factors came together to say actually, if you're going to do it now is the time to do it, and at the time [the university] were ramping up and were very interested in trying to spin companies out rather than just licensing technology. Erm so a number of factors came together to say it was right’ (Pre-Commercial Fuel cell mCHP manufacturer 1ii)

In the second extract we see the participant identifying the value of techno-scientific expertise in and around the firm in terms of the unique knowledge and technological capabilities of the scientists involved. It is this emphasis on unique benefits that provides the link between the market opportunity elucidated above and the expertise outlined here- identifying a market is one thing, being capable of serving it is another. The expertise signified in the extract by references to the technology and scientists is where the participant locates potential value. Reference to the patent signposts the beginning of the embryonic company transforming its expertise into a commercial asset. Simultaneously the participant introduces a new element to the narrative; their University's desire to spin out companies at that time. So we see a triple thrust in which the participant's own reading of market opportunity, to which their expertise is appropriate, combines with an institutional logic privileging company formation as a desirable goal for academic research. This combination of institutional and policy structures, with constructions of context and competence, lead the participant to conclude, 'the time was right' to embark upon pre-commercial practice. Here is an account of a rupture in the individual and organisational identities of actors involved in the early stages of the firm's existence from a more techno-scientific set of competencies and background abilities, to a new set of ideational abilities of a commercial nature.

The above narrative is emblematic of the expertise claims and problem framings of pre-commercial firms in a number of ways. The interpretation of techno-scientific competence and market contexts as opportunities is typical of pre-commercial HFC firms. In mCHP applications Ceres Power and Ceramic Fuel Cells Ltd (CFCL) pay great attention to rising fossil fuel prices and the introduction of government incentives such as feed-in-tariffs as indicative of growing market readiness for their technologies (Ceramic Fuel Cells, 2012, pp. 10-11; 2011, p. 5; Ceres Power, 2012a, pp. 3-4). Similarly in a single annual report, electrolyser manufacturer ITM Power (2012a) provides updates on contextual shifts towards transport decarbonisation; the emerging need for energy storage capacity;

and grid instability emerging from the introduction of intermittent renewables, as indicative of the arrival of a market for hydrogen production and grid balancing products and services offered by the company. It ought to be noted here that in the cases of ITM Power and the above Fuel cell mCHP manufacturers we see the same energy system issue, grid instability, interpreted as heralding market opportunities for two separate technologies; on-grid demand response for ITM's electrolyser units and Fuel cell mCHP distributed generation. This is not to suggest that there can be only one answer to such problems, but rather to highlight the extent to which a pre-commercial firms' specific techno-scientific expertise shape their interpretations of the energy system and subsequent constructions of position.

IV. Incumbents

If pre-commercial firms claim competency in HFC innovation, what competencies are emphasised by larger multi-national corporations with expertise in today's energy systems? Large UK and international energy utilities; fuel retailers; and global producers of automobiles, industrial gas and chemicals all possess expertise and capabilities pertinent to introducing HFC based energy vectors in the UK. In such firms, competence is often unstated, their sheer size and reputations reducing the necessity for emphasis on techno-scientific expertise. That said, competence is still an essential component in the positioning of incumbent firms within the HFC community. In the first instance, claims to expertise in a given market can be deployed to bolster incumbent legitimacy as they enter the new territory of HFCs. For example in a brochure promoting its hydrogen energy services, industrial gas company Air Products boasts;

‘Today we’re a nearly \$6 billion company with 17,000 employees in 30 countries, making chemicals, gases, and related equipment’ (Air Products, 2002, p. 2)

This extract is positioned at the end of the brochure briefly profiling the company and its history.

While the rest of the document details the firm's specific work with hydrogen, noting its established safety record, hydrogen production and refuelling expertise; this section contextualises Air Products'

expertise as those of a blue chip company, serving global markets for chemicals; gases and related equipment. The broader claims within the brochure, particularly around hydrogen production and transport refuelling mark Air Products out as an enthusiastic incumbent, pointing to additional competencies specific to HFC technologies. The quantifications the extract provides operate to demonstrate the size and the reach of Air Products as a global company. The implication of this statement is that while hydrogen energy applications may be minor, non-profit generating activities for the company, Air Products has the size; reach and expertise to make it a success. This type of framing is commonplace amongst incumbent firms, differentiating them from the smaller pre-commercial firms with whom they may collaborate (cf. E.ON UK, 2009; Intelligent Energy, 2012; IE CHP, 2012). Indeed, even when incumbents make claims to leadership in HFCs, for example in the collaborations announced between leading automotive firms developing shared systems, components and standards for FCEVs (Daimler, Ford & Renault-Nissan Alliance, 2013; GM & Honda, 2013); discussion of collaborators expertise in hydrogen are enhanced by notes and reminders of their size and expertise in existing markets.

Caution and Enthusiasm

Although incumbent firms share claims to expertise located in techno-scientific knowledge; size and reach, this does not mean they comprise one homogenous group. Contextual concerns affecting different industrial organisations and sectors inevitably have a bearing on how incumbents interpret and construct HFC technologies. In particular we may wish to distinguish between enthusiastic and cautious types of incumbent. While enthusiasts see market opportunities pursuing HFCs, cautious incumbents view HFCs as potential means to meet future energy system constraints but remain uncertain or sceptical over their capacity to do so. This uncertainty has characterised energy utilities identifications with HFCs to date, and is exemplified in the next interview extract from one utility incumbent manager:

‘So our interest in it is that hydrogen is another of these um fuels which can be used in a number of ways. Once you've created hydrogen you can either um use it in fuel cells to power vehicles... or you um potentially inject it into the gas grid er to reduce the greenhouse gasses in er heating fuels; you can use it as an intermediate energy storage medium and then use it to generate electricity through modified gas turbines. So all these sorts of er, potential uses for it and y'know one of the ways of producing hydrogen is through an electrolyser which obviously needs an electricity supply and that is another key area of interest for us.’
(Cautious Utility Incumbent 1)

Responding to a question about why they were interested in hydrogen, we see several markers of uncertainty throughout the extract. Punctuated by numerous pauses, the participant lists several contextual factors relevant to the utility's business through which HFCs are interpreted; however here and throughout the interview they are reluctant to go into specifics. Here we see a brief listing of potential new markets for the company in electrolytic hydrogen production, mixing with decarbonisation challenges relating to the natural gas grid, and requirements for on grid energy storage driven by anticipated increases of intermittent renewable generation. The quick-fire listing combined with hedging terms ('potential' and 'potentially') and frequent pauses ('um'/'er'), provide a picture of an organisation lacking in expertise in the field and yet to develop a clear understanding of its business impacts. Indeed, the desire to 'understand' formed a key element in this participants wider interview narrative. Given the uncertainty over future markets for hydrogen and regulatory constraints on electricity and natural gas grids, the participant's uncertainty is unsurprising. It ought to be noted that this extract comes from one of the more active utility incumbents in the UK HFC community, who elsewhere in the interview highlighted numerous efforts to become involved in projects and increase their expertise in the technology. Rather than reflecting ignorance of the technology or broader energy system issues, cautious incumbents efforts to understand thus function as a response to uncertainty over the potential of HFCs amidst uncertain regulatory futures.

For more enthusiastic incumbents, the purpose of HFC technologies is clearly defined as a future core business area. Thus, recognising the growth in renewable energy and low carbon technologies more

broadly, Johnson Matthey- a leading chemicals company and market leader in platinum group metals (a key catalyst in PEMFCs), have devoted significant efforts to promoting HFCs as a future growth market. In response it has opened its own fuel cells division and publishes the free-to-access industry publication and online resource Fuel Cell Today. The paradigmatic case of enthusiastic incumbents however lies in the industrial gas sector, and in particular the big three international companies; Air Liquide; Air Products and the Linde Group. Producing a range of gasses including hydrogen for applications as diverse as petrochemical refining; electronics manufacturing and healthcare, these companies have come to view hydrogen energy applications as a potential major growth segment over the coming decades (Air Liquide, 2012; 2013; Air Products, 2013; Linde Group, 2013a; 2013b). Given their existing competencies in production and storage of hydrogen gas, they have invested heavily in developing hydrogen infrastructure and refuelling technologies, at least one developing renewably produced hydrogen production capabilities specifically for use in energy applications. Such efforts position industrial gas incumbents for market contexts in which H₂ may be a major fuel in energy applications.

While industrial gas companies are united in their enthusiasm for HFCs this is not the case in all sectors. For example while the bulk of the automotive industry views HFCs as a long term solution to future landscapes in which resource use and carbon emissions are more constrained (cf. Daimler et al., 2009), some have interpreted this shift as an opportunity to leverage their current and historic competencies in HFC RD&D for market and reputational position. Thus in the UK webpage and press pack for the ix35 fuel cell electric vehicle (FCEV), Hyundai presents the technology as the 'Car of the future', recipient of prestigious engineering awards and demonstrative of the firms competence and commitment to innovation excellence (Hyundai, 2013a; Hyundai, 2013b). This is not to say the pack and Hyundai's surrounding literature ignores the environmental benefits of HFCs, they too are foregrounded elsewhere in the same document. However such benefits are constructed not as

onerous requirements but positive selling points for the vehicle, which in all other respects is comparable in experience and performance to a conventional vehicle. Indeed, this latter point is crucial for incumbent automotive firms' interpretations of the technology. So far as possible the customer experience should remain the same, maintaining a connection to the existing competencies in automotive production and retail they have developed over decades (for expansion on this point, see pp.210-211).

It is this blending of HFC specific competences with the more generic mass market and logistical competencies of the incumbent that allows enthusiastic types to interpret their market contexts as representing opportunities. This is not to imply a clear dividing line between cautious and enthusiastic incumbent. Closely following Hyundai and other enthusiastic automotive firms are others who, while lacking the same level of competence in FCEV development, are nonetheless heavily invested in the technology. We should not see cautious incumbents as HFC sceptics; while they may be hesitant and uncertain they are often among the first in their sector to publicly engage with HFC technologies. Of the 'big six' UK energy companies the 'cautious' utility participant cited above is employed by one of only three currently involved. Also at the cautious end of the spectrum we see firms not traditionally engaged in energy technology or infrastructure provision, who nonetheless interpret HFC programmes as a means of positioning themselves as forward looking, or environmentally responsible organisations. Thus large vehicle fleet operator Commercial Group, have joined a demonstration of hydrogen fuelled vans and provided input into UK H2 Mobility's research programme (Commercial Group, 2012; UKHM, 2013a). In constructing themselves as environmentally sustainable house-builders Crest Nicholson have trialled CFCL's Fuel cell mCHP unit (CFCL, 2012). While such activities are relatively minor engagements, often within the bounds of publicly subsidised and time limited projects, cautious actors in sectors at the edge of the HFC community are likely to be among the early adopters of HFC products. The terms 'enthusiastic' and

‘cautious’ thus function to delineate two poles within the broader category of incumbent; established private companies with high levels of competency in their existing markets, looking to similar contexts of increasing resource scarcity; consumer and regulatory expectations of carbon reduction. Whether such contexts are interpreted enthusiastically as opportunities, or more cautiously as risks, rests more on past experience and emergent competency in delivering HFC technologies than on existing core competence or contextual interpretation.

V. Early Movers

For a minority of pre-commercial firms in the HFC community, meaning is found in more radical interpretations of context than those seen in other actor types. These actors perceive the environmental and resource landscapes the world faces as more pressing than incumbent firms have accepted, necessitating faster introduction of HFC technologies and significant alterations to existing patterns of production and consumption. Similar to cautious and enthusiastic incumbency, the pre-commercial firm and early mover represent two poles of a continuum where firms position themselves at different points. It is not unusual for a pre-commercial firm to call for earlier or faster introduction of HFCs, or to emphasise the disruptive nature of the technology as a broader energy vector. However for the purposes of clarity, discussion here focuses predominantly on the sector in which the early mover type finds its fullest expression - the niche automotive sector.

For early movers future environmental, resource and regulatory landscapes are not mere market opportunities or risks, rather they form a fundamental imperative to alter patterns of production and consumption. This extract from automotive early mover RiverSimple’s corporate Information Pack is archetypal:

‘Business is facing a converging funnel of increasing regulation and decreasing resource availability. Today’s auto industry does what it does brilliantly, but it was shaped by the

prevailing conditions of the 20th century. The constraints of the 21st century are quite different and the existing approach is no longer fit for purpose.’ (RiverSimple, 2010, p. 5)

Above we see RiverSimple provide a narrative of how shifting regulatory and resource contexts are likely to undermine the existing motor industry. The ‘converging funnel’ metaphor nominalises policy and economic processes as naturalistic and unchangeable corollaries of environmental degradation and resource depletion. Flowing from this assessment is the argument that this new landscape poses unique challenges to the competencies of the automotive industry, it is no longer ‘fit for purpose’. RiverSimple offers a backhanded compliment to incumbent automotive firms; they are ‘brilliant’ at what they do, perfectly adapted to the globalised mass production of conventional vehicles. However as the final sentence makes clear, RiverSimple’s claim to competence lies in the belief that the context upon which incumbent competencies are built is undergoing a structural shift. In so doing RiverSimple both interprets and constructs incumbents as mal-adapted to the prevailing conditions of the 21st century. Implicit in the extract and explicit in the wider information pack is the view that incumbent firms are incapable of embracing this new future. Conversely, RiverSimple’s claim to competence rests in more sustainable technological characteristics of flexibility, longevity and resource minimisation:

‘[We have] developed a model that is highly flexible and rewards longevity and resource minimisation as opposed to obsolescence’ (RiverSimple, 2010, p. 5).

This identification with more radical regulatory and market contexts and competencies, and their placement within the company’s investor relations literature operates both as promotion and a filter. In the first instance it frames the company as a desirable investment to a certain type of environmentally aware investor, one who shares the company’s alternate construal of environmental and resource imperatives. Adopting such a radical framing in corporate reporting literature is uncommon. While many pre-commercial HFC firms attempt to advertise their products and services as timely adaptations to future markets; such wholesale rejections of incumbent business models go against the received wisdom and authority of these widely recognised experts. As such they are far

less amenable to equalisation to the ideas and goals of many mainstream investors and potential incumbent partners.

In expressing anti-incumbent sentiments RiverSimple explicitly betrays a normative understanding of what good business in the 21st century will look like. Longevity and resource minimisation will be virtues; obsolescence an outdated vice. Such value laden constructions of context carry with them consequences for early mover's organisational structures and their attempts to raise capital. RiverSimple operates on the basis of an unusual ownership structure, in which shareholders' interests are given equal weight to custodian boards for employees; commercial partners; communities; the environment and users in the appointment of the company board and long term strategic decision making (Riversimple, 2014). The firm has relied heavily on investments from similarly committed investors, in particular the family of Sebastian Piech. Formerly a major shareholder in automotive group Porsche, Piech is now chairman of Singapore based Horizon Fuel Cells and a long term HFC enthusiast.

While not all early movers rely on investment from wealthy individuals, they do tend to employ similar unorthodox funding strategies. For some equity swap arrangements with suppliers, public bodies and research institutes have provided means of obtaining access to funding, resources and staff which would otherwise be unavailable to them. Indeed all early mover firms identified in the study have, at least in the early stages of their development, formed relationships with such allies to reduce overhead costs. The basis of such relationships is varied, for public bodies and research institutions such reciprocal arrangements can help meet their own remit. Coventry University's housing of Microcab provides evidence of impact even in the absence of revenue from the financial stake they hold in the firm. Likewise Arcola Energy's housing within Arcola Community Theatre

reflects the educational and sustainability work built into the Theatre's charitable purpose. Other early movers may have the additional backing of small groups or individual investors who for a range of reasons may subscribe to the more radical interpretations of context and constructions of meaning early movers expound.

As a form of pre-commercial firm, early movers partly claim competence, through reference to techno-scientific expertise. Automotive early movers RiverSimple and Microcab, boast managing directors with backgrounds in motorsport. Expertise in light-weighting and vehicle efficiency are crucial to these firms' claims to offer leaner, greener vehicle designs than those pursued by automotive incumbents (MicroCab, 2011; RiverSimple, 2010). However allied to such expertise we also see a claim based in independence from the compromises of incumbent automotive manufacturers. In the press release announcing the founding of Microcab, its managing director John Jostins explicitly defines the firm in opposition to the 'vested interests' of automotive incumbents (Jostins, 2003). In so doing he differentiates Microcab by alleging incumbents desire to maintain existing production, consumption patterns and maximise returns on existing investments in combustion engine technology. What we see in this and similar accounts is not a questioning of incumbents commitments to HFCs. Rather they claim incumbents existing expertise, production capacities, and reputational considerations prevent them from bringing HFCs to market quickly enough. In contrast, early movers identify as experts free from compromise. The following interview narrative from the founder of a pre-commercial fuel cell firm displays many characteristics of an early mover:

'Well I guess I got bored, so obviously working for [incumbent engineering company], you couldn't ask for much better- amazing people. But it's slow, even then it was pretty obvious it was gonna take a while to get ready. I think for [them] it was either its perfect or we're not doing it. Um and I guess I was impatient.' (Early Mover 1)

In the excerpt the participant shares their decision to move from a fuel cell team in a multinational engineering incumbent to founding their own pre-commercial fuel cell company. The participant cites boredom with the slow moving nature of his employer's fuel cell development, the notion that the technology must be 'perfect' slowing down development and introduction of the speaker's technology. Here the term perfection indicates levels of reliability and performance matching existing fossil fuel powered technology in the same application. It ought to be noted the participant's hedging with regard to their colleagues, and admission of impatience both function to ameliorate the critique of incumbency, drawing attention to other fuel cell enthusiasts remaining in the firm. At the same time eagerness to get on with producing marketable fuel cell products, regardless of perfection is foregrounded as motivating the formation of an early mover firm. Here we see an ideational rupture in which the participant comes to question the identity of the incumbent engineer, in which focus on 'perfection' comes to be problematized as too slow. While continuing to recognise the virtues of this identity in terms of the 'amazing people' and facilities, it is this desire to move faster that characterises early movers' interpretations of their competencies and contexts.

While the above extract reflects the highly subjective interpretations and account of an individual pre-commercial firm founder, it reflects several dispositions common to early mover firms, in particular a desire to move faster than incumbents and acceptance of the technological imperfections this may bring. The confluence of competencies located in independence, and more radical interpretations of the climate and resource contexts, go together in constructing the meanings early movers attach to their strategies for HFC technologies. While not explicitly aiming to displace incumbent firms, early movers instead perceive niches in existing market contexts where their technological competencies are particularly suited. In automotive applications such niches tend to be those favouring short-range, lightweight FCEVs for local use, as taxis and return to fleet vehicles, or in localised car club/rental applications (Microcab, 2013; Macdonald, 2010; RiverSimple, 2010). In other sectors pre-commercial firms displaying elements of the early mover disposition

mirror this approach. Arcola Energy's HFC powered event lighting service and ITM Power's trial ling of hydrogen powered fork lift trucks aim to provide advantages of 'green' off-grid power generation and improved forklift availability (due to elimination of battery charging times), incumbent technologies are unable to match (Arcola Theatre, 2010; ITM Power, 2012). In constructing these niches, early movers see themselves as hastening the broader introduction of low-carbon technologies, by demonstrating what can be done, assuming (as does the broader transitions management literature) that niche success can translate into broader patterns of industrial and environmental transformation.

VI. Summary

Although the above typology (summarised in table 6 below) to an extent mirrors other forms of organisational definition based on size or core activity, it is the role of competence, context and meaning that are of primary interest here. This is to say organisations of similar sizes in the same sector can and do pursue markedly different strategies in relation to HFCs, differences rendered explicable through reference to their own claims to competence and meaningful interpretations of context. Thus automotive firms with well-established competencies in HFCs tend to be found occupying more enthusiastic positions than counterparts with lesser expertise in the technology. Pre-commercial firms looking to different market contexts, do so informed by the particular techno-scientific expertise of their staff. Secondly it should be noted that while the typology operates on the basis of a distinction between context and meaningful interpretations of position, these are not mutually exclusive. Actor's competencies inform the contextual factors they deem relevant, and the meanings they interpret and construct for themselves and HFC technologies. Through this additive process they construct their organisational competencies, identities and interests as equal to meeting emergent opportunities, or threatened by the emergence of different regime and landscape constraints.

This is not to claim competence and context are the only variables at play however. The long-term position of actors within existing energy regimes also has a bearing. It is no surprise that industrial gas companies are uniformly enthusiastic about HFC technologies, nor that utility incumbents are at the cautious to disengaged end of the spectrum. The latter collectively occupy central positions within existing energy policy regimes, which could easily be threatened by unfamiliar technologies and market entrants. Given privatised utilities' shareholder responsibilities to protect corporate value and market share, a certain reticence in engaging with them may be a prudent strategy. Industrial gas incumbents conversely exist today outside the major energy policy regimes of the UK and Europe; should H₂ become a significant vector in future energy regimes, this would represent a sizeable new market for the sector as a whole. A detailed examination of contextual interpretation is not necessary to see the basic economic calculation at work. Nevertheless the typology does capture fundamental differences. Early movers' competency for techno-scientific innovation and action free from 'vested interests', allows them to more radically interpret environmental and resource landscapes. Without specialist techno-scientific competencies, pre-commercial firms have no opportunities to identify. More importantly, as we shall see in Chapter 9; a distinction based on meaningful interpretations of context and competence reflects the strategies different actor types are able to adopt in the constitution and practices of the emergent HFC policy community.

Hinted at in this chapter, but not fully articulated, is a broader institutional landscape which partly informs interpretations of context and strategies for HFC innovation and governance. While these shall be discussed in more detail in the following chapter, it is worth pausing for a moment to consider its limitations. Firstly it should be remembered the above typology (re-presented in table 6 below) remains the product of an analytic marriage between the constructions of HFC community members themselves and a broader theoretical framework. The above categories are ideal types, articulated to make better sense of the HFC community. The distinctions drawn between them are

not absolute. Some organisations straddle two categories; others may seek to move from one to another over time. Even research institutes remaining within the public sector may seek to 'spin out' profit seeking pre-commercial firms in the course of their work with HFCs. Nonetheless, some means are required to reduce the complexity of multiple organisational contexts and interpretations. As analysis progressed, it became clear that typological combinations of competency and context generated particular interpretations of meaning and position; which in turn carried significant implications for how different types of actor interpreted the institutional contexts and practices they encountered and constructed strategies for engagement in HFC innovation governance.

Table 6: Actor Typology

	Dimensions				
Type:	Competency:	Context:	Meaning:	Industry Sectors:	Examples:
Research Institutes	Objective techno-scientific expertise	Energy as impactful research agenda	Utility/impact opportunity	Academia, national labs & research centres	H ₂ FC Supergen Hub
Pre-commercial	Techno-scientific expertise Intellectual Property	Increasing demand for novel energy technologies	New Market Opportunities	FC and Electrolyser Producers	CFCL; Intelligent Energy; ITM Power
Enthusiastic Incumbent	Expertise in existing sectors Techno-scientific expertise in H ₂ and/or FCs	Core markets changing	Opportunities in changing markets	Some automotive & chemical manufacturers Industrial gas companies	Air Products; Hyundai
Cautious Incumbent	Expertise in existing sectors	Core markets changing	Technological and regulatory risk	Some automotive, energy and utility producers Regulatory aware business users	SSE; Tata Motors; Crest Nicholson
Early Movers	Technological expertise Independence from vested interests	Existing regimes unsustainable and slow to respond	Opportunity for niche experimentation and disruption	Niche automotive and fuel cell manufacturers and retailers	RiverSimple; Microcab; Arcola Energy

8. THE INSTITUTIONAL LANDSCAPE

I. Governance Architectures

This chapter sketches the institutional architecture around which HFC community actors are congregating as a policy community or network. This architecture functions as a relatively fixed landscape HFC community actors must navigate in order to access funds for collaborative RD&D ventures, and shape innovation policy and funding priorities to suit their needs. In navigating this governance landscape HFC community actors try to construct and reproduce their visions for HFC innovation by: developing and refining new technologies and business models; expanding to include new commercial and governance allies; articulating and demonstrating visions for future HFC energy systems. Governance institutions are not static bearers of structure however. While they do apprehend HFCs through the lens of pre-existing policy paradigms and organisational remits, actors within them speak and behave as if they possess agency in seeking the input of experts, and in monitoring and reacting to developments and representations made by other actors in the HFC community. The institutions referred to in this chapter were identified in interviews as key points of convergence or orientation for HFC community members as bodies with funding; resources and, in some cases, regulatory powers of relevance to the development of the HFC community. Introducing this landscape, the chapter sketches the organisational arrangements, metaphors and categories of HFC governance, highlighting the key institutional logics through which policy actors have sought to structure their practices in relation to HFCs. While this approach may seem at odds with the desire to provide an actor centred approach to the HFC community, this institutional contextual is vital to understanding some of the central strategic assumptions and practices in which HFC community actors are engaged.

Before launching into a discussion of departments, public bodies and partnerships, it is first worth noting what these actors look to achieve when promoting HFC RD&D. Given the historical shift in

energy system innovation paradigms towards notions of market liberalisation (cf. Helm, 2007; Mitchell, 2008; Winskel & Radcliffe, 2014), it is unsurprising that policy institutions tended to divide competencies between state funding and support for HFC innovation and private sector responsibility for delivery. Thus the European Fuel Cell and Hydrogen joint Undertaking aims to;

‘Place[s] Europe at the forefront of fuel cell and hydrogen technologies worldwide and enable[s] the market breakthrough of fuel cell and hydrogen technologies, thereby allowing market forces to drive the substantial potential public benefits.’ (FCHJU, 2011, p. 4)

Similarly the UK H₂ Mobility Project seeks to;

‘ensure the UK is well positioned for the commercial roll-out of hydrogen fuel cell electric vehicles’ (UKHM, 2012, p. 1)

The above extracts shows two HFC oriented public-private partnerships positioning HFCs as offering benefits to those states and economies ‘at the forefront of’, or ‘well positioned for’, their development. At the same time, references to ‘market breakthrough’ and ‘commercial roll-out’ both emphasise private sector technology delivery as the primary means to realise these benefits. This is a very particular choice, terms such as ‘scientific’ or ‘engineering’ used elsewhere in the discussion of HFC research are here absent, displaced by a commercial or market language in discussion of the concrete roll-out or deployment of HFC technologies at scale. Both extracts fulfil metaphorical and categorising functions central to the conduct of HFC governance. Firstly use of market and commercial terms in each extract operate as modifiers situating HFC technologies within a particular sphere of economic activity, drawing terminology from the established policy discourse of energy market liberalisation to give meaning and legitimacy to the process. In so doing each extract invokes an implicit categorical distinction or boundary between the respective roles of public and private sector members of the partnership. Technological breakthroughs, the driving of benefits and introduction of HFCs are construed as being within the remit of commercial or market members. While both extracts come from organisations self-defining as public-private partnerships, the maintenance of a public/private boundary is not a product of organisational structure. Rather this

chapter argues they reflect an entrenched institutional logic, inscribed across the institutional architecture for HFC innovation governance.

The following sections attempt to track how this commitment is realised in practice across the UK policy architecture for HFCs, in the structure of institutions and operating logics of their staff. In so doing, it seeks to capture the wide range of governance institutions identified by members of the UK HFC community as key funders of RD&D activities; sources of policy relating to such funding; or as sites of policy making of relevance to their work. In the institutions own terminology, they can be broadly divided into three categories; government departments, non-departmental public bodies, and public private partnerships. This distinction refers not only to specific scales of governance and authority. It also reflects a functional distinction through which innovation governance has been (to varying degrees) devolved from government to arms-length bodies thought better able to assess and meet the needs of the industrial and commercial expert communities they serve.

II. Departments

At the UK national level three government departments; Business Innovation and Skills (BIS); Energy and Climate Change (DECC); and Transport (DfT) have interpreted HFCs as relevant to their policy domains. Tightly bound by paradigmatic commitments to liberal markets and limited state intervention, these departments aim to deliver larger policy goals of promoting economic competitiveness, decarbonisation and energy security. It is through the lens of these remits that departments interpret HFCs, tending to do so as relatively peripheral technologies that display potential for contributing to long term policy goals. So hydrogen sits amongst technologies under discussion in DECC's Strategy for the decarbonisation of heating to 2050, in areas ranging from fossil fuel based fuel cell mCHP (micro-combined heat and power) to the injection of hydrogen into the natural gas grid and the longer term possibility of converting this grid to pure hydrogen. Similarly

BIS and DECC's Low Carbon Industrial Strategy, makes a single reference to hydrogen and fuel cells (2009, p. 40). Here HFCs are deployed as one example of the TSB's broader demonstration programme for low carbon vehicles, the overall goal of which is framed as fostering low carbon economic growth and employment. The treatment of HFCs in this document indicates their position; crossing both departments' remit but occupying a background role to more prominent technological 'solutions' to sustainable development.

While the research was initially tasked with a focus on the HFC community in the UK, during fieldwork it became clear no study of this community is complete without some reference to the European Union, a key funder of HFC activities to whom multiple participants referred and were keen to orient themselves. As in the UK, the EU's Directorates for Research; Energy; Innovation and Transport have broad policy remit covering issues of international competitiveness (particularly vis-à-vis the USA, China and Japan); employment; job creation, and sustainable development (European Commission, 2013; European Council, 2000; High Level Group, 2004). These directorates were never mentioned in interviews, seldom in documents, and were not examined in detail during the study. They are introduced here predominantly as a precursor to the far more influential Fuel Cells and Hydrogen Joint Undertaking (the FCHJU- discussed further below), a public private partnership which they partially fund and appeared in texts as a major point of orientation for the UK HFC community. While ultimate responsibility for long term policy affecting HFCs may lie with directorates and departments, they often did not appear in the accounts of HFC community actors themselves. Instead participants cited other autonomous and semi-autonomous public bodies, public private partnerships and industry associations as their most frequent points of contact for accessing public funds or influencing broader funding and policy programmes.

The dispersal of responsibility for HFC innovation in the UK is not the outcome of some ad hoc process. It reflects a deliberate rejection of a single hydrogen coordinating body in favour of the

more dispersed system for funding and governing HFC innovation offered by the UK's existing energy innovation architecture (DTI, 2004). As opposed to centralising decision making in a single body, as was recommended in earlier DTI commissioned reports (E4Tech, et al., 2004); the stated preference for diversity reflects a desire to maintain some distance between central government departments and the innovation communities they serve. This reflects a paradigmatic commitment to technological neutrality associated with the perceived failings of state planning and ownership of industries in the 1970s. Successive governments have thus been keen to avoid the impression they are 'picking winners' between emergent technologies, rather choosing to emphasise a more hands off role setting regulatory and incentive frameworks for low-carbon innovation (DTI, 2003; DTI, 2007; BERR, DEFA & DUIS, 2008; DECC, 2011).

Departmental discourse constructs the state as an unreliable judge of market and technological potential; a task best left to the market, or where a market is yet to be created, those with relevant technological and market expertise capable of making an informed decision. The following account from a departmental civil servant is exemplary of this logic in operation:

'Well, I mean, I – I think organisations like OLEV [Office for Low-Emission Vehicles] and TSB [the Technology Strategy Board], I mean, are probably more customer facing. Er, I shall... I shall be getting criticised for implying that [own department] isn't, but I mean I think; well, I mean, they have a greater level of practical involvement, erm, and therefore, perhaps, over time, their views as to what is realistic or otherwise, erm, you know, are, are, are more soundly based. Erm, but, you know, they, er, they are closer to making things happen' (Civil Servant)

Explaining their preference for channelling innovation funding for HFCs through public bodies, the participant expresses themselves through metaphors of customer service and distance, which construct greater levels of day-to-day contact with HFC community actors ('practical involvement') as facilitating the development of realistic expectations and sound policy. In contrasting the practice of their own department from two public bodies; the Office for Low Emission Vehicles (OLEV) and the Technology Strategy Board (TSB), these and similar public bodies are defined as being more 'customer facing'. The participant appeals to broader discourses of governance and new public

management which see statutory bodies as service providers and their users as consumers (cf. Rhodes, 1996). The customer metaphor here frames the HFC community in a particular way, as autonomous experts on their own needs - the customer is always right. The participants' anticipation of criticism for not being seen to be customer focused is symptomatic of this wider rationale in which practical involvement with customers is seen to lead to efficiency and sound policy.

Metaphors of distance and customer service thus mark a boundary between departments as funders and the public bodies responsible for identifying priorities and allocating resources. While the former is, by necessity operating at a distance over a wider policy area, the greater independence and specialism of public bodies allows them to maintain closer relations with the constituencies they serve. This is not to say government departments have no contact with the HFC community. Via wide ranging reviews; consultations and calls for evidence they do seek information about and from HFC community members and other innovation communities over questions of current and future regulation and incentive structures. However on day to day issues of innovation management departments have tended to cede responsibility to more autonomous public bodies and partnerships.

III. Public Bodies

Referenced in interviews more commonly than national departments, public bodies represent a mainstay of HFC community members' engagement with governance institutions, facilitating the efforts of and channelling funding to, appropriate actors and technologies within the HFC community. It is this channelling role that requires public bodies to remain in close contact with the subsectors of the HFC community they fund. However there remains some variation in how such bodies are structured. While OLEV (the Office for Low Emission Vehicles) functions more as an interdepartmental working group between BIS, DECC & DfT; other public bodies have greater

degrees of independence. The Engineering and Physical Sciences Research Council (EPSRC) and TSB are both arms-length public bodies reporting to BIS. EPSRCs remit is for ensuring the quality and relevance of academic research and training in British science and engineering. TSB is responsible for fostering private sector innovation to promote UK wealth and job creation. Formerly reporting to DECC, the Carbon Trust is a self-financing not-for-dividend private company, it continues to form a major plank of innovation policy delivery by running technology assessments and innovation competitions on behalf of DECC. Underscoring their independence from government and proximity to the communities they fund, both TSB and Carbon Trust emphasise the industrial expertise of staff and managers. providing online profiles of board members and in-house experts which foreground their private sector experience in energy extraction and generation; finance and management consultancy (Carbon Trust, 2014; TSB, 2013). Similarly EPSRC draws its Council and Scientific Advisory Committees from senior positions in UK academia and prominent Engineering and technology companies (EPSRC, 2014b; EPSRC, 2015). Non-departmental public bodies such as the Carbon Trust; EPSRC and TSB have been delegated the task of assessing the needs of the HFC community in terms of research and project funding, while others such as OLEV have taken on longer term policy and infrastructure planning for hydrogen transport. In referring to these bodies, participants tended to emphasise them as enablers, providing funds that could be used to pursue future RD&D efforts.

For their part, public body civil servants tended to interpret their roles in similar ways to those constructed by their departmental counterpart quoted above. They maintain proximity to HFC community members in order to generate soundly targeted and focussed RD&D funding calls and project programmes. The extract below from one such public body employee describing their role is indicative of such efforts:

‘Er, it’s running around the country visiting businesses and talking to them. Sometimes I get to do that in a workshop, and we’ll get a bunch of people in a forum through the KTN [Knowledge Transfer Network] and, and have a discussion around an area with flip charts and

all the rest of that normal stuff. And sometimes it's me picking up the phone and saying, "Look, can I come and visit? It'd be really good to talk to you about this, understand what you're trying to do here".' (Civil Servant 2)

The overall image portrayed in this account is one of frenetic activity; 'running around the country', picking up the phone, and hosting workshops conjure s an image of mobility and busyness involving great variation in the locations visited and people met. Reference to the KTN here refers to the HFC specialist subgroup of the broader Knowledge Transfer Network for Energy Supply and Generation , a free membership organisation run by the TSB to facilitate networking and information sharing between academia, industry and government (Fuel Cells and Hydrogen Group, 2014). At the same time the participant's language speaks to a degree of familiarity and informality through which the y perceive their relationship with the wider HFC community. Their capacity to be seen to 'run around' and get a 'bunch of people' together in a forum is a reflection both of their status within the community as a project funder, but also of the types of relationships they seek to engender with the community they serve. The participants stated willingness to visit (as opposed to calling meetings), and pick up the phone to determine convenience also speaks to the logic of expert customer service guiding their work. Their short and to the point conversational style ('look, can I come and visit?'), and preference for face to face meetings speaks to a business-like yet responsive attempt to respond to the needs and timetables of HFC community experts. That the participant constructs their practice in this way reflects their broader interpretation of their remit, understanding and facilitating business efforts to commercialise HFC technologies. In this light, activity that initially appeared frenetic, rather fits well within the guiding logics of realistic; customer focused and informed policy making, developed via close proximity to experts. It ought to be noted here the participants focus on understanding does not necessarily relate to the empirical aspects of HFC development, which can be equally well communicated in product specifications and research reports. They also wish to understand the practical challenges RD&D projects can be designed to address such as; access to knowledge and laboratory equipment; finding collaborators, customers and investors; or managing transitions to volume production and manufacturing processes. . It is the practical experiences of

these challenges that public bodies seek to understand in order to better design and support HFC innovation governance.

IV. Public Private Partnerships

Public-private partnerships (PPPs) marked the most frequently and enthusiastically mentioned institutional form in interviews with HFC community actors. Characterised by higher levels of collaboration between HFC community actors and political authorities; PPPs were spoken about in relation to the setting of agendas and allocation of collective resources for HFC development and deployment. However, the overall purpose and functions of PPP's vary significantly.

UK H₂ Mobility is a PPP bringing together representatives of BIS; DECC and DfT with representatives of the automotive; energy; electrolyser; fuel cell; fuel retail; and industrial gas industries (for membership list see appendix 7 p.265). This consortium aims to accelerate the market introduction of hydrogen vehicles and associated infrastructure in the UK through a programme of collaborative research, business and regulatory planning. Conversely the European FCHJU is a public private partnership between the European Commission and two not-for-profit membership organisations; the Industry Grouping (IG) representing the European fuel cell industry, and N.ERGHY representing the European HFC research community. Established via Council Regulation 501/2008 the FCHJU was granted a budget of €450 million from 2008-2012, a sum to be matched by Industry Grouping membership fees and in kind contributions to the running of collaborative RD&D projects. As such the FCHJU combines the characteristics of a public body providing RD&D funding, with those of a public private partnership actively encouraging cooperation and coordination between industrial; research and governance actors to promote the development of a European HFC industry. At more local scales, PPP's have been established in Aberdeen; Birmingham; London and Teesside, with a

view to leveraging local planning capacity; academic and business expertise to accelerate local economic growth and bid for national and European funding for HFC RD&D projects.

It is within PPPs that the policy metaphor of partnership finds its fullest expression. While departments and public bodies emphasise the need for proximity to expert communities in the development of sound innovation governance, PPP programmes at the local ; national and European level aim to generate a range of benefits via the engraining of such relations into their organisational rules and structures. While public bodies have sought to enact partnership via the structure of their boards and consultation procedures, PPP's go further in attempting to inscribe not only proximity but industry leadership into their organisational decision making structures. Local and regionally based PPP's display a great degree of variation in their institutionalisation; from relatively informal arrangements around particular demonstration projects seen in Birmingham, to more formalised arrangements such as the Hydrogen London partnership. While the former functions as a loose network incorporating the city council ; local universities and a selection of more or less locally based FCEV manufacturers; consultancy firms and industrial gas companies (Birmingham City Council, 2008; 2011; SWARM, n.d), the latter is housed within the Greater London Assembly itself; is chaired by a Deputy Mayor and involves a broad swathe of HFC research institutes; pre-commercial and incumbent firms with interests in developing HFCs in the capital (Hydrogen London, 2012, p. 2). In both cases however, the role of local authorities themselves is limited to providing secretarial support and facilitation for infrastructure and planning decisions, leaving research and industrial experts to give the lead on what technologies; projects and funding opportunities to pursue.

Similarly at the FCHJU, while representatives of the European Commission are employed in secretarial roles, the primary direction for technological priorities and funding allocation is an industry led process. This is reflected both in the organisational structure of the Undertaking,

wherein the industry grouping controls 50% of the seats on the governing board and takes central positions in committees setting the FCHJU's strategic research agenda; annual and multi-annual RD&D priorities (FCHJU, 2014, pp. 45-49). The following extract from a senior FCHJU official describing the process of drafting Annual Implementation Plans (AIPs), exemplifies this institutional commitment to industry led decision making:

'It's a consensus- consensus making process where the people are being put together into one room, and we only open the door again when they have a consensus of what needs to be called. I mean that's the way it goes, they have to come out with one plan of what they're going to call for in the next year; and yes there are political, how to say, forces pushing back and forth a little but that's what we expect to come out. So that's why it's also called the public-private partnership where the industry is leading, the industry is giving the direction' (FCHJU Official)

The above account is paradigmatic of a tension between two key concepts at the heart of the FCHJU's governance procedures; 'consensus' and 'industry leadership', which form the central metaphors around which the participant organises their account. Consensus is not merely the preferred outcome of decisions, it is mandated; 'the door' does not open until unanimity is reached. While 'political forces' push back and forth, the ultimate goal is the production of agreement. Consensus does not pre-exist the meeting, it is made. Here 'political forces' stand as the antithesis to sound decision and policy making, implying self-interested organisations seeking to steer funding in areas suited to their own agendas. Interestingly, in other interviews academic and industrial participants also used the term 'political' to identify self-interested activity, always in the conduct of others. Politics came to signify ugly and inappropriate interjections in rational policy deliberation. The above participant's delicacy in word choice; 'how to say', reflects the perceived vulgarity of non-consensual deliberation and the desire to find rational compromise. Consensus in contrast is positioned as a rational expert view of the priorities to which all participants can subscribe. It is this deliberative process which makes partnership possible. Cutting across this description of consensus however is the notion of industry leadership, wherein the direction of travel is provided by Industry Grouping members. The repetition of the term industry in the final sentence, underscores the central

position the Industry Grouping occupies in the partnerships deliberations and organisational structure. If consensus is to be made, it is a consensus for the benefit the nascent fuel cell industry with researchers taking a supporting role. This is not to say every member of the FCHJU (or other PPP's) must take part in every activity the partnership undertakes. Rather, consensus decisions and actions are expected to be to the benefit of the wider industry.

While the terms 'consensus' and 'industry leadership' are particularly prevalent as organising metaphors for the FCHJU, these terms (industry leadership in particular) and close variants on them also appeared in the texts of some UK public bodies and HFC community interview participants as metaphors for various innovation governance processes. Uniting these disparate actors and institutions was a series of metaphors located around concepts of commercialisation (market leadership; industry leadership; customer facing) and partnership (customer facing; partnership; consensus); which fulfilled similar functions in specifying the legitimate means by which HFC innovation governance should proceed, and the goals it should serve. Rather than constituting a particular paradigm of innovation governance then, the FCHJU's emphasis on 'consensus' and 'industry leadership' is better considered a particular institutional articulation of broader policy logics of commercialisation and partnership. These logics were not unique to the FCHJU, but affected UK institutional structures and discourses as well and are best thought of as engrained at an ideational scale that transcends both governance architectures.

While the large scale and highly structured approach the EU adopts via the FCHJU is notably distinct from the less structured efforts of UK institutions, viewed through an ideational lens the two bear significant commonalities in their shared inscription of commercial and partnership logics. Given the thesis' focus on UK HFC innovation governance, its constraints do not afford the space for detailed interrogation of the variegated experiences of market liberalisation and industrial policy reform that would be likely be required to specify and explicate these differences adequately. While such a

comparative exercise may well yield important variations, our attention here should be limited to the significant similarities in the logics of commercialisation and partnership underlying HFC innovation governance in both polities.

V. Partnership, Categories and Boundary Interpretations

While policy actors and HFC community members tended to emphasise partnership and consensus as key means of forming sound innovation policy, their deliberations in general and those of PPPs in particular can be highly bounded activities, involving clearly defined and recognised categories and criteria for membership and participation. At its most basic level, this bounding was expressed in terms of ‘industry leadership’ and public private partnership, through which governance institutes sought to defer technological decision making to research institute and industrial experts. In constructing HFC innovation as set of commercial and partnership relations, policy actors and institutions specify particular expert constituencies as relevant for inclusion and consultation, while relegating others to lower levels of participation or exclusion. This section does not seek to describe the specific categories and means by which every governance institution bounds the roles of the expert groups it recruits to inform policy. Rather it outlines key features of this boundary work in two high profile PPPs; the European FCHJU and the UK H₂ Mobility Consortium. This is not to suggest that such boundaries are unique to these institutions or to PPPs as an institutional form. Rather it is in these organisations’ widely published structures and rules that more general categories of inclusion, marginalisation and exclusion are rendered most legible.

FCHJU: Bounding the Undertaking

Within the FCHJU and its precursor consultative bodies and technology platforms, deliberation over innovation goals and specific RD&D priorities have tended to be conducted by working groups in five Application Areas (AAs); Transport & Refuelling; Hydrogen Production & Storage; Stationary Power & CHP; Early Markets and; ‘Cross Cutting Issues’, the latter covering issues of regulation, training and

education to support market entry for HFCs (European Hydrogen and Fuel Cell Joint Technology Platform, 2005; FCHJU, 2011). Recruited from prominent industrial and research organisations interested in these sectors, membership of AA working groups reflects the broader categorical differentiation policy actors draw between themselves as facilitators and funders; researchers as providers of objective knowledge, and; commercial organisations as deliverers of end technologies, product and systems. As such, since 2008 AA working group memberships have been exclusively drawn from FCHJU's industry and research groupings (the IG and N.ERGHY). Never problematized within the FCHJU's organisational discourse, this categorisation assumes research institutes and industrial actors alone hold the key to unlocking the future potentials of HFC technologies. However relations between the two categories are not equal. Given the Undertaking's emphasis on commercialisation and industry leadership it is unsurprising that industrial organisations are constructed as of singular importance within its partnership structure. This extends not only to the industry grouping's 50% control of the FCHJU's governing board (relative to the 10% and 40% controlled by N.ERGHY and the EU Commission- see Appendix 8, p.267, and; FCHJU, 2014, pp.45-49), but also in the way research institute actors feel authorised to participate in the deliberations of working groups.

The following extracts, taken from the official website of the FCHJU's research grouping (N.ERGHY) is indicative of the boundaries members recognise in their assigned roles within the Undertaking. Discussing working groups in two application areas, these extracts construct distinct roles and opportunities for researchers as relative to the distance of each HFC application from market. Thus, the AA group for transport is constructed in terms of 'domination' by the more powerful interests of the IG:

'This AA is dominated by demonstration activities and the Industry Grouping (IG) is actively pursuing their major interest of getting vehicles on the road, and this is clearly reflected in IG's priorities.' (N.ERGHY, 2009a)

Conversely, the lower budget area of hydrogen production, storage and distribution³ is depicted as a research intensive field further from commercialisation, in which N.ERGHY members have more space to contribute:

‘This AA is dominated by research activities and therefore the ideas of N.ERGHY are very well recognised within the actual annual implementation plan.’ (N.ERGHY, 2009b)

In choosing to publish these two extracts on its website, N.ERGHY constructs the FCHJU in terms of a differentiated range of opportunities for research institutes depending on their AA expertise. As technologies in a given AA move closer to market, the requirements of the Industry Grouping are granted greater priority. The second extract in particular points to N.ERGHY’s strategic interpretation of the FCHJU, in which those AAs dominated by research, as opposed to demonstration or product focused activities, are more susceptible to academic influence and research priorities. Given the underlying programmatic logic of FCHJU projects, wherein the development of techno-scientific competence is seen as a precursor to more market oriented activities (see Chapter 8.VI, p.181); the space currently given to N.ERGHY in the AA for Hydrogen Production and Storage may be liable to shrink as emerging technologies move through the FCHJU’s programme. In publicly presenting this description on its website for current and prospective members, N.ERGHY is not seeking to critique the FCHJU or AA working group structures. Rather the above extracts appear as a strategic guide to researcher participation in the partnership, highlighting the best opportunities for research actors to become involved in AA working groups.

The above extract illustrates how institutional emphasis on industry leadership and commercialisation become deeply embedded in the strategic calculations and interactions of community and policy actors, enacting strong boundaries around the areas and forms of input different types of actor are authorised to provide. In most circumstances such bounding formed an

³ Between 2008 and 2013 the FCHJU’s target budget for transport was three times higher than that for Hydrogen production, standing at 36% and 12% of spending in each AA (FCHJU, 2014, p. 26).

implicit assumption or unwritten rule built into the institutional assumptions of HFC community and governance actors. Thus when questioned about participation of environmental NGOs within its Stakeholders advisory group, FCHJU members and officials expressed a certain amount of confusion. In responding, such participants stated that it was not that such groups were barred from membership, rather they could think of limited reason why NGOs would wish to attend. While space is provided for such categories of actor in the stakeholder advisory bodies built into the FCHJU's governance structure (see Appendix 8, 267), the category of environmental NGO was simply not one they considered relevant or sought to involve in their work. In such instances what we see are a set of implicit assumptions deeply embedded in the institutions and actor networks involved in HFC governance regarding the appropriate actors to be engaged in HFC innovation. These assumptions affect not only the membership rules of collaborative governance institutions but also the way such rules are interpreted and acted upon in recruitment to and the day to day running of their deliberative and advisory bodies. While N. ERGHY members and NGOs can in principal contribute to AA working groups and Stakeholder advisory meetings respectively, in practice they are expected to have limited roles. It is this expectation, driven by logics of commercialisation that shapes the participation (or lack thereof) of different categories of expert in partnerships for innovation policy development.

The Exclusive Logic of UKH₂ Mobility

While the boundaries for participation in the FCHJU remain in principal relatively porous, reliant on its staff and members interpreting a commitment to commercialisation from its organisational discourse and structure, one governance institution was more exclusive. UK H₂ Mobility (UKHM), a PPP geared towards the commercial roll-out of FCEVs and associated infrastructure in the UK (see p.168); adopts a more restrictive range of criteria to limit participation. While ostensibly an open consortium, UKHM requires new members be able to; 'demonstrate an ability to play a significant role in contributing to the co-ordinated roll-out of hydrogen-fuelled vehicles and refuelling

infrastructure in the UK' (UKHM, 2014b). While it is not clear what such a demonstration might involve, the national scope of the sentence combined with the phrase 'significant role' indicates incumbent competencies of size and reach are likely to be important. Similarly, the focus on the roll-out of physical vehicles and infrastructure suggests a bounding of the overall discussion. It is only the ideas and visions of those expected to be contributing to this roll-out in practice that qualify for membership- research institute experts and broader stakeholder groups need not apply. In addition membership fees act as a secondary filtering mechanism within UKHM. While the FCHJU also charges such fees, costs there are relatively low and no organisation interviewed cited these as a barrier to participation. Although subject to the FCHJU's confidentiality agreement, multiple participants (including an enthusiastic and cautious incumbent) cited UKHM fees as prohibitively expensive. When questioned on this, interview participants tended to respond through references to commitment and simplicity, accepting exclusions as necessary to ensure a swift research and reporting process and commitment on the part of members. As one pre-commercial participant discussing fees put it:

"It's enough so that there are no people around the table who are not committed to making it work; err or who, who hadn't thought about it. There are no err pressure groups or anything. It's largely companies and err and the audience around the table. And that's very important to make sure that we have a business-oriented outcome that can make sense with respectively the Government." (Interview with Pre-Commercial UKHM Participant)

This extract is indicative of the categories and logics of exclusion UKHM members seek to employ. In the opening sentence the participant interprets fee levels as a guarantee of commitment to the broader goals of the project. Willingness and ability to pay is equated to rational forethought and commitment to the goals of the consortium. As one of only two pre-commercial members, the speaker is here highlighting their own organisation's commitment to the aims of the consortium. Despite their limited resources they have the commitment to pay to participate in a PPP of national significance. Unprompted, the participant specifically identifies civil society organisations, 'pressure groups,' as key categories of expert actor to be kept out. Conversely the description of the

consortium as ‘companies’ and ‘the audience around the table’ depicts the participants desired composition, wherein committed companies conduct research and planning, for the benefit of a governmental audience. While the wording in this sentence is somewhat unclear, audience potentially referring to other companies in the consortium, the notion of government as audience is reiterated in the final sentence. Here we see the participant’s understanding of the ultimate purpose of the project: a ‘business oriented outcome’ to be communicated to government.

Interestingly outside of UKHMs membership, contestation of this pattern of exclusion was largely non-existent. Speaking to one niche-automotive provider an account emerged in which UKHM was seen as something for industry incumbents, too costly and grandiose in its aims for smaller players to participate in:

‘I do know quite a few of the partners and people in it [UKHM], but it’s very much an OEM [Original Equipment Manufacturer]/government agency kind of, consortium, it’s not really, it’s not... because we can’t offer much industry pull compared to say, Toyota or whatever, it’s not for us to sort of, to be involved, I think that’s the way I’ve seen it anyway.’ (Niche FCEV manufacturer)

The above extract illustrates the success of UKHM’s boundary work in deterring organisations lacking incumbent expertise from applying for membership. While the participant’s own firm would fit into the category of Original Equipment Manufacturer (OEM), here the term is being deployed to refer to the larger players; automotive and industrial gas incumbents, and those larger pre-commercial firms who have been successful at inserting themselves into incumbent automotive supply and value chains. The sentence the participant begins but never finishes; ‘it’s not really, it’s not...’ has only one conclusion that they chose to articulate differently, UKHM is not for them. Taking the cue offered by the consortiums requirements for a ‘significant contribution’, the participant recognises their own limited capacity to offer ‘industry pull’. This is not to say they question the legitimacy of UKHMs boundaries. Elsewhere in the interview the participant describes friendly relations with other UKHM

participants, particularly Intelligent Energy and ITM Power who remain members of the same associations; networks and conference circuits as the participant. Subsequently in the same interview the participant expresses enthusiasm for the new refuelling stations they hope UKHM will provide. What we see here is the effect of the overarching logic of expertise at work within UKHM and the HFC community more broadly, as a smaller player with radically different vision for future mobility systems (for a brief discussion see Chapter 7.V, especially p.157); the participant views themselves as unsuited to meeting the goals of the consortium.

While UKHM is a particularly exclusive governance institution with clear limits on who can be involved, the underlying categories and logics behind its boundaries mirror those of the FCHJU and other governance institutions. While ostensibly open organisations seeking to identify the best tasks and technologies for the roll-out of HFCs, such openness is significantly constrained and shaped by commitments to commercialisation, privileging the input of industrial organisations in general and incumbents in particular. These commitments are built into the organisational structures and membership categories of these two PPPs in the relative weight assigned to N. ERGHI; the IG; and advisory bodies at the FCHJU; and the fees and membership criteria of UKHM. However the exclusive framing of aims and participation in highly techno-scientific and economic terms is by no means unique to these bodies. Such framings operate at an ideational level, shaping how PPP members, employees, and non-members interpret their roles and capability to influence governance decisions.

In so doing such organisations legitimise particular forms of participation over others, limiting the scope of discussion to the relatively narrow set of techno-economic questions their members are competent to address. This is not to say such limitations are essential products of the institutional structures governance institutions adopt. Both UKHM and the FCHJU claim some level of openness in their membership and governance structures. Neither specifies the precise techno-scientific competencies they require, and the FCHJU has specifically developed additional advisory fora for

states and stakeholders. In so doing these partnerships anticipate the possibility that other competencies and insights may at some point be required in the introduction of HFC technologies. However in adopting a strong narrative of commercial purpose and techno-scientific expertise, these partnerships tend to discourage alternate forms of participation. In some instances such as the pre-commercial UKHM member cited above this is a strategic advantage, speed and simplicity are important goals, allowing for a clearer case to be made with government. The boundaries and exclusions enacted by PPPs and other governance fora, thus reflect a degree of ambivalence at the heart of partnership activities, between openness and purpose; consensus and industry leadership.

VI. Projects

The final aspect of the governance architecture discussed in this chapter refers not to a particular organisational form as such, but to a collection of practices referred to by policy and HFC community actors alike as 'projects'. Unsurprisingly, given their status as the key tool policy actors have at their disposal for promoting HFC innovation, projects were the most ubiquitously mentioned governance practice in interviews and documents. The term occurred in reference to academic research programmes, larger multi-company RD&D programmes, and even some PPP activities such as UK H₂ Mobility. For the sake of simplicity, henceforth reference to projects will be limited to publicly funded RD&D activities, leaving to one side other partnership activities dealing with issues of policy or large scale technology deployment. Nevertheless, the term 'projects' belies the wide range of practices supported by policy actors, from small business advice and mentoring for pre-commercial firms to large, multi-country field trials and demonstrations of HFC products. While the institutional remit of different public bodies and PPPs limits to a degree the kinds of projects they tend to fund⁴, there is a considerable degree of overlap between the goals of bodies such as the TSB, Carbon Trust

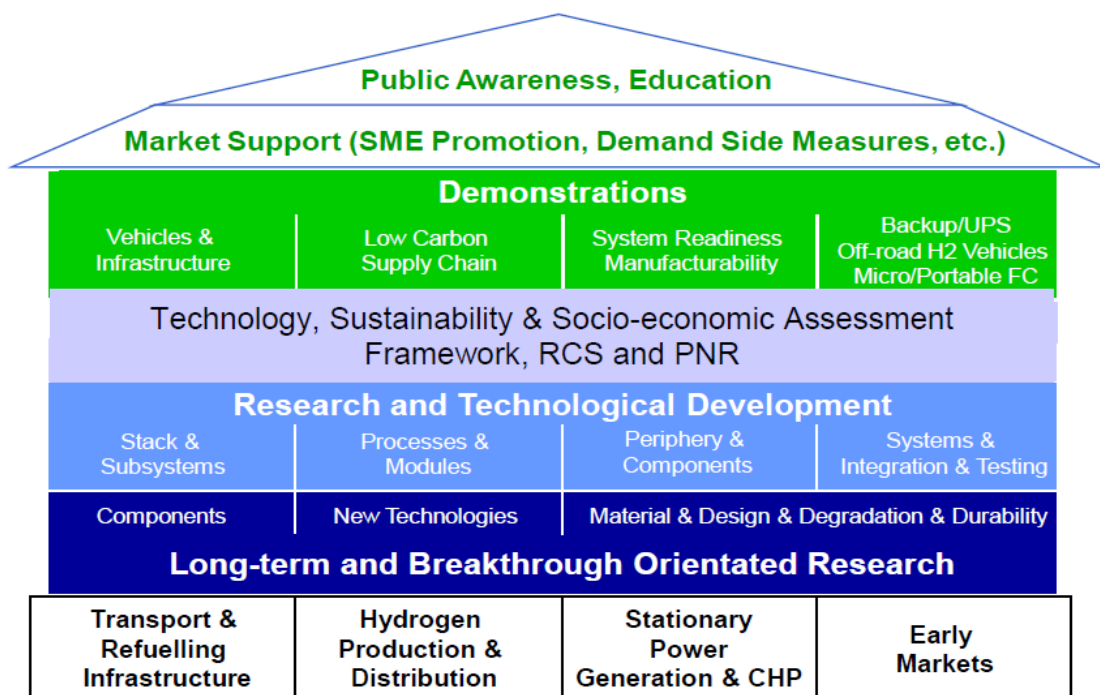
⁴ The EPSRC being a research funder in UK Higher Education is unlikely to fund large scale commercial field trials unless they contain a significant academic component; similarly the TSB does not fund research with a purely academic focus.

and FCHJU. As such we see a plethora of RD&D programmes across the governance landscape, each using slightly different terminology but reflecting similar overarching rationales.

Public funding of projects begins from the assumption that on their own, no single actor within the HFC community is capable of commercialising a complete HFC energy system. Reasons given for this difficulty in interviews with policy actors and HFC community members varied, however almost all fell under two broad metaphors for market failure; 'the chicken and the egg' and 'the valley of death'. 'Chicken and egg' problematisations dealt with questions of sequencing and coordination in applications requiring substantial infrastructure provision, wherein fuel cell and infrastructure providers each lacked incentives to bear the risk of going first deploying their technologies. 'Valley of death' problematisations focused on the distance between the development of a concept or product and realisation of sales revenue, which mark a key period of vulnerability for pre-commercial firms during which they experience high running costs for RD&D and low income. . Both metaphors begin from the assumption that commercialisation of HFC technologies remains the ultimate goal and legitimate means for pursuing HFC introduction, while at the same time problematizing the uncoordinated and competitive nature of commercial markets in achieving it (House of Commons Science and Technology Select Committee, 2013). In so doing, these metaphors operate to rationalise and legitimate departures from the day to day assumptions of liberalised energy and industrial policy to allow for a degree of intervention by state actors to support the commercialisation of desired technologies. The embedding of these metaphors in HFC innovation projects operates to frame both the range of activities that can be legitimately undertaken and the categories of actor and action required.

We see the embedding of chicken and egg and valley of death metaphors most clearly in the RD&D project programmes adopted by public bodies and PPPs to support HFC innovation. The diagram in figure 3, taken from the FCHJU’s Multi-Annual Implementation Plan (MAIP) is exemplary in this regard. Covering the broad range of project aims that are dispersed across the remits of multiple UK public bodies, it orders distinct goals of HFC innovation towards the ultimate goal of commercialisation, in so doing pointing a bridge across the ‘valley of death’ and providing an overarching structure through which coordinative questions can be addressed.

Figure 3: MAIP Structure
 (Source: FCHJU, 2011, p.6)



Drawn from the FCHJU’s Multi-Annual Implementation Plan; figure 3 orders distinct goals to be achieved by projects into a single arrow, signifying a six staged process through which HFC technologies are to progress towards the eventual goal of commercialisation. Long term breakthrough oriented research, feeds upwards through research and technological development; technology assessment; demonstration; market support and public awareness programmes. At each

stage the MAIP allocates funds to support ongoing RD&D efforts, aiming to both accelerate the process of innovation and avoid the potential for emergent technologies to fail on route to market. While the integration of these phases into a single programme is unique to the FCHJU, we see across the UK governance architecture a similar array of project programmes oriented towards similar goals. Thus EPSRC's attention to long-term basic research corresponds to the FCHJU's category of long-term and breakthrough oriented research, focussing on the development of emergent ideas and technologies such as novel forms of hydrogen production which, while not essential to early market introduction, are likely to provide valuable refinements to future mass market HFC energy systems (EPSRC, 2006; FCHJU, 2012a).

Moving up the diagram 'Research and Technological Development' aims to translate basic science into marketable artefacts and systems; often integrating components and competencies of multiple actors into a single artefact or production system. Projects conducted under the auspices of the TSB's Manufacturing and Supply Chain Competition are indicative of this aim, funding firms to increase their scale production facilities; redesign products for mass manufacture; and develop systems for component providers to insert their products into the fuel cell stacks and systems of supply chain partners (TSB, 2014).

The third stage of the JU programme; 'Technology assessment', is in the UK produced via a range of academic research centres including the Supergen Hub and UK Energy Research Centre, and also a key activity for the Carbon Trust and Department sponsored consultancy reporting cf. (E4Tech et al, 2004; H2FC Supergen, 2013; UKERC, 2014). Combined with market gauging and planning activities, often supported by PPP's (cf. Hydrogen London, 2012; UKHM, 2013a), such activities aim to refine

future innovation priorities and coordinate industrial and regulatory expectations with a view to eventual market introduction.

‘Demonstrations’ allocated 41-46% of total funding in the MAIP; returns the focus of projects to the development of concrete artefacts, specifically the trialling of complete products and systems, often with real life customers in public settings. Demonstration activities such as the FCHJU’s SWARM FCEV demonstrator play a dual role in project discourse, incentivising the development of HFC supply chains; infrastructures and scale manufacturing processes, while showcasing the feasibility of HFC energy systems prior to full market entry (SWARM, n.d; FCHJU, 2012b). In so doing demonstrations act to stimulate early markets for FCEVs, while testing the latest generation of products and systems in anticipation of market introduction. Due to the order of magnitude difference in budgets between the FCHJU and UK public bodies and PPP’s, it is the primary funder of UK based demonstration programmes. However at smaller scales, the TSB has also piloted small scale hydrogen based energy generation and transport systems (TSB, 2012a), while local authorities and PPP members have often contributed resources to the running of FCHJU and their own smaller scale demonstrations.

The final two tiers of the diagram; ‘Market Support’ and ‘Public Engagement’ tend not to be pursued unilaterally but rather alongside the former project goals mentioned; referring to actions designed to enhance the business networking expertise of pre-commercial firms, and prepare future consumers for the arrival of HFC products through demonstration programmes. The Carbon Trusts’ PEM Fuel Cell Challenge initially conducted a technology assessment, and addressed through its funding call the latest developments in PEMFCs with potential to drive substantial reductions in FCEV costs (Carbon Trust, 2012b). Successful applicants took part in market support projects, receiving business advice and networking support to gain access to incumbent automotive manufacturers.

In dividing the market introduction of HFCs into discreet project goals, governance actors seek to support the HFC community and channel its emergence as a network of actors geared towards collective goals of coordinated market introduction. Rather than funding individual actors to pursue their own purposes unilaterally, the overarching structure of the European and UK project programmes operate to integrate each stage of the RD&D process into a channel through which emergent technologies can progress to market. The collaboration between actors incentivised in the development and demonstration of completed HFC systems, likewise seeks to incentivise collaboration between actors of different type and in different sectors to work together, developing confidence in emergent technologies and coordinating efforts towards technology deployment and market introduction. While maintaining the boundary between academic and industrial experts and policy making, the structuring of projects in this way functions as a key form of meta-governance, guiding actors seeking funding towards the key technology areas of interest for UK and European energy innovation and the eventual goal of marketable HFC technologies.

VII. Summary

What we see in the emergent institutional architecture for HFC governance is a polycentric collection of public bodies and PPP's with overlapping remits in different geographical and sectoral areas of the UK and European innovation system. Geared towards the market introduction of HFC's and operating according to shared logics of deference to industrial and research expertise, their work can be read as enactments of two overarching logics captured in the metaphors of commercialisation and partnership. These logics delegate governing authority from centralised departments of state to partnerships and public bodies, deemed to be closer and more responsive to the needs of research and industrial experts, and better positioned to make sound decisions as to market potential and technological priorities. Underpinning this institutional architecture is a set of categorisations which

broadly distinguish between researchers as generators of independent techno-scientific knowledge and assessments; industry as the appropriate users of this knowledge for the delivery of products and systems; and policy actors whose main role is to support these actors on route to commercialisation via the provision of project grants and coordination activities. Such boundaries serve both to delineate the appropriate roles different categories of partner should take, and distinguish between desirable and undesirable forms of membership.

Given these logics and categories, it is unsurprising that categories of HFC community member identified during data collection took the forms they did, nor that they identified public bodies; PPP's and projects as the primary reference points for their interactions with policy actors. Such arrangements are not simply the result of bottom up practices of lobbying and political engagement made by that community. Rather they reflect an entrenched institutional logic which while differentially realised, cuts across both UK and EU approaches to energy and innovation policy; categorising and specifying the appropriate roles for research; commercial and policy actors, and coordinating their partnerships towards the overarching goal of market introduction.

To claim that the institutional landscape for the HFC community is governed according to logics of commercialisation and partnership implies that this community does not pre-exist governance processes. Given that HFC community actors routinely included shifting energy system regulation and research funding priorities in their organisational narratives, this is difficult to deny completely. However, given the broader global environmental and resource contexts several actors in the community invoked, it would be difficult to argue their existence and constructions of meaning are solely predicated on UK and EU policy architectures. In seeking proximity and partnership with an HFC community, policy actors both assume its existence and call it into being, drawing lessons and leadership from it while shaping its emergence. As such, the UK policy architecture for HFC

innovation and the HFC community seem to exist in a state of co-evolutionary emergence, each shaping and being shaped by the other, in the context of more global ideas around decarbonisation and the appropriate roles of the state and market. It is to this mutual shaping the following chapter turns.

9. STRATEGIC PRACTICE IN THE HFC POLICY COMMUNITY

I. Constructing a Policy Community

Thus far, the thesis has laid out the institutional architecture through which the HFC community moves, and a typological description of the actors comprising this community. Such a description is of little relevance without an accompanying discussion of how these fit together; both in terms of relations between actors of different types, policy actors and governance institutions.

Notwithstanding the distinctions enacted by logics of commercialisation and partnership, the specialist competencies that define different actor types tend to limit their activities to developing smaller components, devices or sections within wider energy system evolutions. HFC innovation governance thus takes relations between HFC community actors as its starting assumption. Pre-commercial firms seek investment and orders from incumbent industries and national funding bodies; cautious incumbents seek knowledge of fuel cells through participation in industry bodies and collaboration with pre-commercial entities. Public bodies aim to facilitate and accelerate these processes. This chapter examines the main collaborative practices through which the HFC community is enacted, via participation in professional networks and collaborative RD&D. In addressing these practices, it examines the strategies through which different actors pursue new competencies, knowledge and understanding of HFC technologies and seek to shape the priorities of innovation governance in terms of funding allocations and regulatory planning.

This account does not aim to be universal, purely commercial partnerships and investor-investee relations do exist outside of the partnership networks established between policy actors and members of the HFC community. These commercial relationships are addressed in this chapter to the extent that, in many instances, participation in public-private partnerships and projects is constructed as contributing to organisational reputation and investor confidence. However the main emphasis is on collaborative practices involving policy actors and institutions, as it is in these fora that we see the HFC community taking shape as a network for innovation governance.

The following chapter examines four key varieties of collaborative practices through which the HFC community is constituted; conferences and networking; project participation; project planning; evidence creation and lobbying. As with the above discussion of the institutional landscape, each variety of practice discussed in this chapter emerged in interviews and documents as a key site of strategic partnership practice and positioning for actors in the HFC community. This is to say practices were identified in cases where multiple actors spoke to the importance of a particular variety of practice (i.e. conferences as a key site for partnership building and consortia formation), or in some cases where several different actors referred to the same enactment of that variety of practice (i.e. the Hannover Messe Fuel Cells conference as a key site of conference activity). The resulting analysis does not present these participant descriptions unaltered however. Overlaying descriptions of practices and participant interpretations of their roles within them, is a discussion of how and why particular actor types adopt the strategies and positions they do in relation to particular forms of practice.

In so doing, this chapter seeks to characterise the HFC community in terms of what Foucault, and those following in his footsteps might term its strategic situation or field of power, the complex of relationships through which differentially positioned actors draw on the institutional resources at their disposal to act out their own strategies, affect and respond to the strategies of others (Foucault, 1989, pp. 71-79; 2003; Flyvbjerg, 2001, p. 122). This is not to suggest the HFC community sketched in this chapter constitutes a single strategic alliance, or some collection of multiple competing interest groups. Rather it is to suggest that the innovation governance in the HFC community is constituted through the strategic interactions of differentially positioned actors taking part in it. .

Conferences & Networking

Conferences and networking activities provide key sites in which the HFC community is articulated, drawing policy; research; pre-commercial; incumbent and early mover firms, and sometimes governance actors to a single collectively experienced event. In interviews participants often cited attendance at conferences; networking and briefing events hosted by project funders as key to generating a sense of shared identity; goals and trust within the HFC community. At the same time, discussing their own participation at such events, participants made it clear attendance was by no means a neutral practice. Events were constructed as sites of strategic positioning and engagement in which actors attempt to make themselves known as credible potential partners with something to contribute to prospective investors and collaborators.

Beyond their stated aims of bringing together the HFC community for the purposes of networking and knowledge sharing, conferences within the HFC community have a variety of aims. Individual conferences may be categorised according to application; fuel cell type, or; distinguished between 'technical conferences' aimed at fuel cell type or application specific experts and those with more generalist themes. Thus the Birmingham International Conference for Hydrogen and Fuel Cells has for the past two years, divided its programme between an opening generalist day focussed on broad policy directions; funding opportunities and visions for HFC energy systems, and technical days focusing on scientific reporting and detailed discussion of systems and components in particular applications (Climate Change Solutions, 2014a; 2014b). The European Fuel Cell Forum's Lucerne Conference is more technically oriented. Alternating annually between high temperature fuel cells (predominantly SOFC) and low temperature PEM technologies, Lucerne aims to facilitate focussed discussion of specific technology challenges and closer ties between narrower expert communities. This distinction between technical and generalist events serves to mark different orientations of networking practice; the former framing outward looking attempts to attract non-specialists such as

policy makers and cautious incumbents; the latter looking inwards at specific technical challenges and cutting edge solutions.

The goal of conference attendance varies between different types of organisation. At the technical end research institute actors spoke of a desire to disseminate research findings and develop impactful partnership relations with industrial organisations. Pre-commercial firms tended to refer to the search for new research, emerging market trends and a desire to find partners with competencies in sectors related to their own interpretations of market opportunity. Enthusiastic Incumbent firms tended to give less prominence to technical conferences in their accounts, those who did offering similar rationales to their pre-commercial counterparts. Conversely attendance at generalist conferences and research funder organised briefing events tended to be framed by all actors as a means of learning about emergent policy and funding goals. For cautious incumbents with little prior knowledge of the technology, such events offered a means of learning about the field and identifying potential projects through which they could gain low risk experience working with HFCs. Enthusiastic incumbents and pre-commercial firms conversely saw generalist events as public platforms to articulate their own visions for HFC futures in the hope of shaping emergent agendas for HFC innovation and commercialisation, in order to attract new commercial and project partners. The below interview discussion from a pre-commercial electrolyser manufacturer exemplifies the mixed dynamics present in conference practice:

‘When we speak at conferences we want to be saying things that provide thought leadership. A lot of the big industrial companies, when they have a new idea that no one’s doing they keep it to themselves. For a small company the best thing you can do is tell everyone and try and lead thinking, that way people will remember you and come and visit... One of the best things we do in networking is having people come visit our factory.’ (Pre-Commercial Electrolyser Manufacturer)

The strategy outlined above was indicative of several pre-commercial and early mover narratives regarding conferences, in which attendance was constructed as a precursor to commercial and

project relationships and the investment they bring. Categorising their firm as a 'small company', the above participant constructs their presentational strategy via differentiation from those of larger incumbents ('big industrial companies'), both in terms of presentation content and their overall aims. In this account it is not that incumbents do not seek opportunities to present, but they are constructed as adopting a careful approach to what information they place in the public domain. Perhaps wary of setting difficult to achieve goals or damaging established reputations with more speculative statements, incumbents are presented as keeping their more innovative ideas secret. In contrast, the participant's strategy is predicated on their smaller stature and reputation; they wish to be seen as innovative and memorable. Demonstrating thought leadership functions as a rhetorical equaliser for pre-commercial firms, compensating for their smaller stature and differentiating them from others in their field. While incumbents may possess reputational and resource advantages, their very reputation as low risk investments means they lack the freedom to make statements as bold and radical as those of pre-commercial organisations.

This account reveals a picture of conferences and networking events as strategic spaces where firms position themselves as prospective collaborators. Incumbents merely need to demonstrate their presence in the HFC community. Smaller firms seek to turn their limited reputations to their advantage, offering radically innovative ideas and technology in the hope of being noticed. Thought leadership strategies thus bear some similarities to the overall position adopted by early movers. However they do not necessarily entail the adoption of a radical early mover position, rejecting incumbent competencies. They can also operate to position pre-commercial firms as potential partners for cautious incumbents lacking the confidence to take on riskier innovations internally. The eventual goal of making such statements is not just the distinction of being seen to lead. As the final line of the extract demonstrates, the goal is to translate recognition into networks and factory visits from potential investors, partners and research funders.

While conference presentations; networking and visits represent tools for pre-commercial firms to attract potential partners and funding, this goal is not shared by all actor types. Academics tended to narrate conferences as opportunities to disseminate research findings and engage in new collaborations, and by extension generate industrial impact. Such actions are indicative of contextual requirements on researcher institute actors to continue attracting limited funding for RD&D from project funders and larger incumbent firms whose size and reach provides greater resources for HFC RD&D. For their part incumbents attend such events in a position of relative power. While some incumbents (including the cautious utility manager quoted on p.146) interpreted conferences as a means of enhancing their understanding of HFC technologies and potentials, they do not require them to sustain their core business activities. This may explain why, for enthusiastic incumbents in particular such practices were accorded far less prominence. While such events afford some opportunity to shape expectations of future markets for HFC technologies, relative to the larger scale public demonstrations and partnership activities in which they are engaged such events are of relatively low impact. While pre-commercial and research institute actors compete for attention, incumbents in attendance are relatively free to pursue more cautious presentational strategies.

II. Project Participation

At the heart of conference and networking practices is the desire to report on past, and build consortia for new projects. Across interviews 'projects' was deployed as a catch all term referring to a variety of collaborative practices geared towards HFC RD&D. Having already briefly summarised the overarching logics of projects in HFC innovation governance, this section examines the ways in which different actor types have engaged in projects to further their organisational interests. Within the community 'projects' can refer both to collaborative relationships generated and funded solely within the community, and those conducted under the auspices of departmental, public body and

FCHJU funding schemes. This section deals primarily with the latter, although many of the logics and practices discussed here may well hold for projects conducted between commercial organisations. If the development of publicly funded projects is informed primarily by logics of commercialisation and market failure, the enactment of projects in practice assumes a desire on the part of different types of actor to gain access to competencies beyond their existing capabilities. Project participants seek to enhance their knowledge of the technologies they are developing and their fit into wider energy systems and markets. Bolstering capabilities through project participation reflects a collaborative process through which different actor types seek to interpret and equip themselves to face future regulatory and market landscapes.

For research institutes, project participation can provide a valuable source of grant income, and several academics interviewed highlighted collaborations with 'industry' as valuable in ensuring the relevance and utility of their research. Combined with EPSRC requirements for industrial impact, built into the funding criteria for specific projects and broader funding agendas (EPSRC, 2006; EPSRC, 2010; EPSRC, 2011); participation in collaborative projects with industry tended to be constructed as the high point to which research institute activity aspired. Surprisingly early mover firms and enthusiastic incumbents displayed remarkably similar constructions of project practice, showing particular enthusiasm for demonstrations. In these accounts demonstration was constructed as a means of testing latest generation HFC products, while at the same time illustrating the feasibility of their respective visions for the technology. Enthusiastic incumbents tended to discuss demonstrations as a form of pre-market preparation activity, ironing out potential technical bugs and spreading the word about HFCs. Conversely early movers constructed demonstrations as a means of showcasing the possibilities for their alternate business models and visions for life in more carbon and resource constrained energy systems. However, perhaps the significant role of projects was in their capacity to draw more cautious incumbents into emergent networks for HFC innovation to

support the commercialisation of pre-commercial technologies and it is on these relations the remainder of the section focuses.

For more cautious incumbents, and even some teams within more enthusiastic firms, projects were interpreted as a means of engaging at relatively low levels of cost and risk with HFC technologies. Perhaps even more significant is the additional authority the existence of project funding can lend to technology teams and HFC specialists within incumbent firms, arguing for greater resources to be diverted towards the technology. The following account from a technologist employed by a cautious energy utility is exemplary of the way project funding can be deployed to modify the interpretations of HFCs within such organisations:

‘Even bizarrely to companies like [us] who could quite well afford to do it without the help, it actually makes it easier if we can go to the board and say; I know it’s costing us [£]5,000,000, but we’re getting [£]5,000,000 from the EU as well so y’know, we’re getting value for money... And it’s sort of a confidence thing, er it’s not just the money it’s the fact that somebody out there thinks what we’re doing is worthwhile.’ (Cautious Utility Incumbent 2)

Discussing their experience of participation in FCHJU funded projects developing fuel cell mCHP, the participant situates project funding in a wider narrative of their efforts to promote the technology within their company. Here the authority to divert funds to HFC technologies lies with the company board, their decisions contingent on a range of concerns. While the participant believes the firm possesses the necessary resources, they interpret the boards as cautious and reluctant to invest in the emergent technology without some form of commercial incentive. Recognising this context, the participant first describes availability of European funding as providing a ‘value for money’ legitimisation for the proposed project, allowing appeals to financial logics to justify the additional expenditure. At the same time, the participant relies on the implicit authority of the EU to legitimise their work with HFCs as a ‘worthwhile’ pursuit. In so doing, they imply the existence of not only a financial incentive, but also the implicit threat that future integration of EU energy markets and regulatory regimes may require utilities to engage in higher degree of energy efficiency technology

promotion- a theme they returned to repeatedly in the interview. The provision of project funding thus operates as a means of empowering smaller technology enthusiasts within larger incumbents to draw their companies closer in the HFC community.

The above extract does not refer solely to the cautious utility, rather it was raised in the context of discussion of ongoing project collaborations with a pre-commercial fuel cell mCHP manufacturer. Press releases from both firms involved in this project, construct the collaboration in terms of a sharing of competencies in which the utility is the beneficiary of bespoke mCHP technology for its own trials retail operations, while the technology provider gains access to orders and funds for continued development of their product; manufacturing and logistical systems. In this way the project functions to bridge the boundaries between the distinct organisational capacities and competencies of each party.

Viewing project participation by HFC community actors as a mutually beneficial activity does not mean RD&D risks are evenly shared. Often incumbent involvement can be hesitant and subject to change. In a limited number of cases incumbents have left the HFC community on project completion, 'capturing'⁵ the knowledge gained pending the arrival of more commercially viable futures for the technology. More commonly, memoranda of understanding underpinning incumbent relationships with pre-commercial firms allocate payments and investments according to phased project 'milestones'. Such agreements provide incumbents with access to pre-commercial HFC technologies, while minimising their exposure to the costs and risks of internally conducting RD&D. Linked to the release of further partnership investment and prominently enshrined in the business plans and investor reporting of pre-commercial firms, 'milestones' were narrated as essential steps in

⁵ The term 'knowledge capture' was deployed by one cautious incumbent in particular, reporting on their experience of participating in and ceasing engagement with HFC technologies in the UK and globally. Due to confidentiality constraints providing a fuller description of their efforts is not possible

the process of realising market opportunities (Acal Energy, 2011; Ceres Power, 2011; ITM Power, 2011; IE CHP, 2012).

In outsourcing fuel cell development to pre-commercial partners, incumbents both limit their own liability should the technology fail to materialise, and gain a degree of input into the product design and development timetable (Ceres Power, 2009; E.ON UK, 2009; Acal Energy, 2011). This is not to say pre-commercial firms derive no benefit from such arrangements. Intelligent Energy's 2014 IPO, raised £40m of investment, partially on the back of their reputation for successful collaborative projects (The Financial Times, 2014; Winand & Maguire, 2014), and; prior to Ceres Power's withdrawal from manufacturing complete Fuel cell mCHP units, their partner British Gas made over £2million in milestone payments in addition to taking 9.9% equity stake in the company. Moreover in announcing project partnership updates via press releases, often automatically linked to investor relations pages and external finance and stock listings websites, pre-commercial firms seek a reputational boost in their search for further investment. However, within such strategic partnerships, it tends to be the pre-commercial actor that bears the brunt of financial and reputational risks. When Ceres Power missed milestone targets in its product field trials, British Gas invoked its right to withhold payments leaving Ceres to collapse (Ceres Power, 2012b; The Telegraph, 2012). While the incumbent was left out of pocket, Ceres was forced to radically alter its interpretation of the market opportunities available for its technology. In continuing to trade the restructured company has had to abandon its strategy of becoming an end product manufacturer and is now operating a licensing business model in which its core technology will be embedded in incumbent manufactured products.

What we see emerging in actors constructions of project participation can thus be read as a process of strategic engagement with the overarching institutional framework for HFC innovation governance. Actors of different types interpret the possibilities for project participation in light of

their own contextual interpretations and competencies. These interpretations also structure their relative power in engaging with project practice. While incumbents enjoy position in existing markets and possess resources for the independent pursuit of their preferred technologies, pre-commercial firms need project grants, together with the additional investor confidence and commercial credibility they bring. Thus while project funding may go some way towards ameliorating 'the valley of death' experienced by pre-commercial firms and technologies, it does so by reinforcing the lock-in of incumbent firms and their preferred technological trajectories. This strategy has advantages in enrolling cautious incumbents that may otherwise be reluctant to participate in HFC innovation. However, given the unequal position of these actors and their pre-commercial partners in existing market contexts, it is unsurprising that project agreements and memoranda of understanding tend to outsource financial and reputational risk to pre-commercial firms.

In building a commercially driven HFC community by funding strategic partnerships, projects and their funders incentivise and instantiate a range of commercial relations and dependencies between pre-commercial technology providers, incumbent manufacturers and end users. It is too early to say what the outcome of such partnership models may be, however they are a far cry from the niche innovation to regime transformation models which have characterised most previous cases of sociotechnical transformation studied in the broader literature (Christensen, 1997; Rip & Kemp, 1998; Geels, 2012). Instead the institutional logic of commercialisation and partnership being pursued aim to encourage innovation within incumbent led socio-technical systems, maintaining and reproducing the pre-existing imbalances of power between incumbent and pre-commercial actors.

Project Planning & Funding Allocation

By offering a way to establish and develop partnerships between actors in the HFC community, project programmes aim to bring the overarching commercialisation goals of HFC innovation

governance closer to realisation. The process through which such programmes are developed forms the focus of this section. While the design of RD&D programmes is partly a product of broader institutional logics of commercialisation, decisions regarding the technological criteria on which project funding should be allocated have tended to be delegated to deliberations within PPP's or produced through the networked forms of engagement pursued by public bodies. These deliberations do not function to enact the HFC community as a single entity. Instead they operate as sites of strategic communication between HFC community actors and governance institutions, through which future RD&D funding priorities are negotiated. In helping to shape agendas for RD&D funding, HFC community actors seek to ensure that their technological interests will be reproduced in supportive RD&D programmes. This is to say project planning itself is a key site of strategic manoeuvre in which, HFC community actors seek to collectively construct project programmes sympathetic to their own organisation's development.

Within the HFC's governance architecture a broad range of practices are geared towards the design of HFC innovation projects. From the informal visits, workshops and knowledge transfer networks used by public bodies to highly structured and formalised processes employed by PPPs such as UK H₂ Mobility and the FCHJU, two standout features emerge. Firstly, as was specified in Chapter 8, each form of governance institution was committed to a form of expert led decision making. Close consultation involving industrial organisations in particular, is a key criteria for public bodies and PPP's policy making and even departments are expected to consult widely over future regulatory directions. Secondly, consultation practices tended to be structured to allow for the involvement of a relatively broad cross-section of the HFC community. Not all research institutes, pre-commercial and incumbent firms enjoyed the same status in designing project programmes and allocation of funds. However, at least in principle processes of programme design and funding allocation are open to a range of actors.

Deliberative processes displayed high degrees of flexibility and complexity, allowing a wide array of interactions which were difficult to capture given the methodology being pursued. The researcher was not present in workshops and project design working groups, nor able to observe one to one meetings between funders and HFC community actors. When asked, participants often struggled to discuss specific meetings in detail; sometimes due to confidentiality issues, and in part we may speculate due to the length and variety of such meetings relative to the breadth of interview discussions. However, most participants seemed to believe their presence within such fora had positive outcomes on eventual project funding criteria. This was especially true for non-incumbent actors who felt, without their presence, funding may converge around a narrower band of incumbent favoured technologies and priorities. The following extracts from a pre-commercial fuel cell mCHP manufacturer stands out, both in the participant's reluctance to enter into specifics and in their perceptions of their influence in such meetings relative to incumbents:

'So [we have] sat on a number of those bodies to make sure that the funding calls when they come out are erm broad enough to make it attractive, not just to the big incumbents. Erm and that I think we've been fairly successful at doing, particularly this last call. I think the disappointment then comes when you look at the number of projects they can support under those, you know, ones or twos, automatically by their definition against risk, will tend to favour a bigger organisation, they've done it before, and they're deemed to have the horsepower to deliver it.' (Pre-Commercial Fuel cell mCHP manufacturer)

The extract begins with the participant's rationale for attending funding body meetings both in the UK and the EU, linking broadness of the call (the technical criteria against which project bids will be judged), to the likelihood of the firm obtaining funding. Here broadness is constructed positively, in opposition to narrow calls that may function to benefit large incumbent firms. Such a construction is predicated on the participant's self-categorisation in opposition to 'big incumbents' possessing the resources to attend all such meetings. Incumbents for their part are not defined by the participant, but their use of the term seems to be in the colloquial sense of large industrial companies as opposed to the more specific definition offered above. This opening sentence implies that the

speaker believes that if they did not attend and provide oversight, larger firms would be willing and capable of generating a narrower consensus around their preferred technologies, locking pre-commercial competitors out from applying for project funds. The participant's sense of success in preventing this speaks to the space multiple governance institutions try to afford a broad range of partners in the design of funding calls and project programmes. This is not to say non-incumbent actors are willing or capable of maintaining membership of all such bodies; as one pre-commercial electrolyser manufacturer put it; 'I could spend my whole life going to "interesting" European meetings' [emphasis theirs]. Rather they seek to engage such bodies strategically, attending only those bodies and meetings where relevant and sympathetic funding discussions are likely to take place.

Developing a capacity to make such judgements is itself a learning process for HFC community actors, the above reference to success 'particularly in this last call' speaks to a growing competence in engaging project funders. Continuing their narrative however, the participant claims that despite such successes, the limited number of projects which can be funded means bid assessors tend to favour larger organisations thought to have the size and reach to make them a success. Whilst partially accepting this risk averse logic, the participant is nonetheless disappointed that otherwise open processes can still lead to outcomes favouring larger organisations. In claiming processes of RD&D planning and funding allocation were to some extent skewed towards the benefit of incumbent firms, the overwhelming majority of pre-commercial firms and other non-incumbent actors interviewed sought means to overcome the biases they perceived. One automotive early mover expressed limited confidence in their ability to effect funding agendas ('if you're a policy maker who're you going to listen to Daimler Benz or [us]?'), others adopted more strategic responses. Assertions of 'thought leadership'; project collaborations with incumbents and strategic meeting attendance, all reflect tactics to influence funding agendas while minimising the risk such efforts will be wasted. For one research institute actor collaborating with a coalition of early mover

automotive firms and an industrial gas incumbent, bidding for funds was itself a strategic exercise, timed during a year when total funds available were too low to attract competing bids by automotive incumbents.

In interviews with incumbents, participants did not interpret their participation in funding deliberations as an exercising power, rather participation tended to be framed in highly rationalistic terms. Technical standards such as refuelling pressure for FCEVs, embedded in recent criteria for FCHJU funding calls and the assumptions of the UK H₂ Mobility Partnership⁶ were presented as the neutral product of customer expectations, and what was technically feasible for a mid-range family vehicle to carry. To incumbents no controversy had taken place, however, for several early mover and research institute participants, this shift was seen as effectively limiting public support for more radical schemes. In particular the phasing out of lower pressure refuelling was interpreted as a threat to more radical transport system innovations based on short range private vehicles; multi-modal public transport and shifts to novel vehicle share and leasing business models.

This is not a question of whose account is empirically accurate. It is entirely possible those actors with alternate interests simply were not present at the range of European and international meetings where pressure standards were agreed upon, or that they took the strategic decision that engaging in a long running controversy would not be a productive use of their limited resources. UK H₂ Mobility does not feature research institute or early mover participation (for full list of consortium participants; see Appendix 7, p.265), and so likewise these concerns would not likely have been raised. However, the case of refuelling pressures does illustrate an imbalance of power between different actor types within the HFC community. Participation is relatively open but the capacity to influence is unequally distributed. If we accept the notion that RD&D funding hopes to shape the

⁶ UK H₂ Mobility assume high pressure 700bar refuelling as the standard for new stations; at the FCHJU successive funding calls have seen standards shift from 350 or 700bar for demonstration projects to a requirement for all refuelling station stations to be capable of providing the more expensive 700bar standard with 350bar becoming an optional extra (FCHJU, 2009; 2010; 2011; 2012c).

emergence of particular types of technology and commercial producer, then this unequal relationship may carry longer term consequences for the range of HFC technology that reach commercialisation. It effectively filters out those that do not conform to competencies or meaningful interpretations of future markets favoured by incumbent organisations.

III. Evidence Creation and Lobbying

Not all engagement between HFC community members and governance actors requires face to face meetings however. Research institutes and coalitions of industrial organisations have, through a variety of reporting styles, sought to influence the development of RD&D funding criteria, as well as the broader regulatory environments for the emergence of particular HFC technologies. Several participants did not construct such activities as lobbying; preferring to think of themselves providing relatively neutral knowledge inputs into policy deliberations. This section uses the term as shorthand to describe all attempts to inform policy making decisions regardless of stated intentions. The rationale is to provide a shorthand label for the type of practice being described, varieties of which will be discussed in more detail as the section proceeds. In so doing the chapter sketches how the more neutrally framed lobbying efforts of research institutes seeking to recommend the optimal role for HFCs in future energy systems, have nevertheless been shaped by their interpretations of liberalised markets and research impact. It then moves to examine how incumbent and pre-commercial firms have sought to develop collective voices to lobby for favourable regulatory environments for their preferred technologies; deploying many of the same documentary strategies as research institutes, and seeking to identify the correct policy language with which to frame their claims. The final part of the section turns again to the power of incumbent firms in framing collaborative research questions and evidence creation practices, steering collaborative evidence construction towards outcomes favourable to their visions for HFC technologies. In so doing the

section draws together preceding discussions of research, partnership and incumbent power and highlights the ways in which strategic practices help reproduce the interests of incumbent actors.

Interpretation and Objectivity

Lobbying, in the sense of the provision of data to inform public policy making has been a central task of HFC research institutes, and individual academics. The International Journal of Hydrogen Energy makes explicit reference to political and economic aspects of the technology in its author guidelines, and several institutes seek to influence funding agendas via the generation of research publications and technology summaries. The UK Energy Research Centre's Research Landscape documents outline UK capabilities in HFC and technological assessments mapped against the global market potential for HFC products and services, with a view to identifying optimal areas for further RD&D in line with national policy (Brandon, 2013; Dutton, et al., 2013). Responding to successive calls by DECC (2012a; 2013) for research into the long term potential of fuel cell mCHP in the decarbonisation of domestic heating, the H2FC Supergen Hub's recent white paper on the technology takes such efforts a step further in seeking to inform long term regulatory planning for wider energy systems (Dodds & Hawkes, 2014). In interviews discussing the use of research outputs to inform long term innovation and energy system governance, research institute actors did not tend to construct their work in terms of the manipulation of funding agendas, but as part of an objective effort to highlight the specific applications in which the technology may have a role to play. The following extract and discussion from the narrative of one senior research institute professor and public body consultee illustrates this insistence on objectivity:

'You can't just champion fuel cells regardless. I think you have to truly understand where their strengths lay and where their weaknesses lay, so that you can provide a balanced, high-level picture.' (Research Institute Professor 2)

Responding to a question about their work 'championing' (a term borrowed from earlier in the participants own narrative) HFC technologies, the above extract is indicative of the claim research

institute actors make of objectivity as a core competence they possess. Disputing the premise of the interview question, the participant is keen to emphasise they do not 'champion' the technology as an end in itself. In contrast to an earlier discussion of fundraising work for their research centre (in which such championing was seen as vital to securing project and other forms of grant funding), here the participant constructs their advisory work with public bodies, and publications in support of it, as balanced. Understanding of weaknesses as well as strengths and a high level systematic view of the wider UK energy system are here interpreted as essential in the role of evidence production and lobbying. However, in seeking to provide evidence of use to policy institutions, research institutes interpretations of policy priorities necessarily come to shape their problem framings.

Later in their interview, expanding on the high level picture they perceived, the above participant outlined a range of strengths and weaknesses HFCs possess in transport; CHP and grid balancing applications, providing heavy emphasis on their market prospects should they be 'brought through at the right price'. In adopting a commercial terminology for their systematic account, the participant implicitly accepts the overarching commercial logics informing their organisational context and the wider institutional architecture for academic HFC research.. In the participant's narrative, this acceptance serves to underscore their own objectivity, however this objectivity is guided by a commercial logic that specifies what it is to be an impactful research actor. This form of commercialised interpretive process was universal to all research institute actors interviewed, while a minority maintained some ambivalence towards the market power of some incumbent actors, the prevailing assumption was that the need for marketability was as much an objective criteria for HFC introduction as the techno-scientifically measurable factors of HFC efficiency and performance that characterise their empirical research.

The claim to being producers of evidence was not unique to research institute actors. Evidence production in the support of lobbying activities was a common strategy for a range of incumbent and pre-commercial actors seeking to make their case for specific HFC technologies. One energy utility participant heavily engaged in fuel cell mCHP projects provided a prolonged narrative regarding a successful series of trials conducted with trade association and project partners, seeking to dispute the findings of a less promising Carbon Trust study of that technology. While evidence production was positioned at the forefront of the incumbents account, they were keen to position this within the context of a broader industry and trade association led lobbying effort:

“We need to believe that we can influence the policy makers to provide a framework in the market that means the technologies actually do what they're meant to do. So as much as the kind of technology development, we are quite active in lobbying and you know, and not just the lobbying itself but providing the evidence to support the lobbying.” (Cautious Utility Incumbent 2)

In the above extract, the participant's 'need to believe' (as opposed to a simple belief), reflects their experience of disputed process of evidence production they had experienced in relation to a public body technology assessment for mCHP technologies. Nevertheless, as the remainder of the extract makes clear the participant organisation's lobbying practice remains predicated on the hope that policy can be influenced through the production of evidence. In framing their lobbying activities in terms of evidence and ensuring regulatory frameworks incentivise technologies 'do what they're meant to', the incumbent actor seeks to claim the same mantle of objectivity as that of the research institute professor. This is not interested lobbying but rather an effort to develop sustainable and manageable future energy systems. As with the professor however, the utility manager's criteria for system efficiency is shaped in part by their organisational context and competencies; in this case as a network distributor for electricity with substantial expertise in fossil fuel domestic heating technologies. Immediately preceding the above extract, the participant provided a longer narrative problematizing solar photovoltaic forms of micro-generation for their unstable generation profiles and daylight limitations. While the latter is a more generic problem associated with solar energy, the

former implies a significant challenge to the centralised mode of electricity generation and grid management their organisation is competent in. This is not to suggest that the participant conflates their own corporate interest with objective evidence production, but rather that such interests and competences shape the interpretive framework through which their objective for the criteria for judging what a given energy technology is 'meant to' do.

We see similar interpretive shaping in the collaborative evidence production of the UK H₂ Mobility Partnership, aiming to specify the requirements for high pressure hydrogen refuelling networks. In so doing the partnership gives substantial emphasis to 'consumer requirements' gleaned from market research with target fleet and private consumers for major automotive firms (UKHM, 2013a, pp. 6-12). In their research reporting, the partnership repeatedly deploy markers of scientific rigour in describing its 'robust fact based analysis', and 'credible roadmap' for FCEV deployment, providing methodological information detailing surveys and focus groups held with current and recent purchasers of new (petrol or diesel drive train) vehicles. In adopting the requirements of current major automotive firm customers as the central category for specifying how emergent FCEV systems should function, UK H₂ Mobility unproblematically adopts the current interpretive framework of its largest membership group as the sole criteria by which successful commercialisation can be objectively predicted. Alternate models based on public transport deployments; multimodality; leasing and car club models favoured by early movers (Microcab, 2013; RiverSimple, 2010) or H₂ combustion; methanol and other niche based FCEV expansion scenarios developed wider academic literatures (Eames & McDowall, 2010; Ekins & Hughes, 2010a), are simply not considered.

Collective Voices

In engaging in lobbying activities, commercial firms in general and incumbents in particular, recognise the potential for their interventions to be interpreted by others not as the objective

outputs of disinterested researchers but as shaped by their commercial concerns and interests. Such concerns found voice in interviews in two ways; the first outlined by consultants and trade association actors tended to focus on the fear that multiple industrial claims had the potential to disorient policy actors and institutions, undermining the potential for the collective articulation of more coherent claims on behalf of the industry. The second related concern which was left more implicit, was the notion that individual lobbying created the potential for individual firms to be left 'out on a limb' (Cautious Utility Incumbent 2); being seen to articulate relatively narrow sets of organisational interest at the expense of the wider HFC community. Given such concerns, there appears to be a clear preference in the lobbying strategies of commercial organisations to submit representations collectively where possible; via partnership activities such as UK H₂ Mobility, or; via the formation of industry associations.

In articulating potential innovation pathways; providing long term technology assessments for preferred HFC technologies; and responding to public consultations, actors within the HFC community have often opted to lobby collectively via industry associations and collectively funded consultant authored studies (Ecuity, 2013; Fuel Cells UK, 2005; Hayter, 2014). In interview narratives, there was no single body emphasised. Rather actors tended to gravitate towards sector specific bodies such as the Society of Automotive Manufacturers and Traders; the MicroPower Council; and Combined Heat and Power Association (CHPA). These wider industry bodies were afforded greater prominence in interviews than the more technologically specific UK Hydrogen and Fuel Cell Association (UKHFCA). Incumbent industrial gas manufacturers and some pre-commercial actors seemed to lack links into technology specific bodies, preferring to ally themselves with organisations more closely aligned to their technological competencies.

In several interviews more technologically inclusive, sectoral associations were constructed as more effective at influencing regulatory development. Testing the accuracy of such perceptions was beyond the bounds of the study, however a brief examination of DECC's 2011 consultation on Feed-in-Tariff bandings for non-photovoltaic technologies suggests this may be the case. The three utility incumbents that responded to the consultation did so alone, or as members of the technologically non-specific MicroPower Council and Combined Heat and Power Associations. This group made coordinated recommendations for generation payments of 15pence per kilowatt hour (p/KWh)⁷. Additionally the associations made a collective request for a review of the 4.5p/KWh flat rate payment for export to the electricity grid (CHPA, et al., 2011; CHPA, et al., 2012; SSE, 2012) to better reflect the benefit of heat driven CHP technologies over their renewable counterparts⁸. Conversely the major UK based mCHP manufacturers maintained a dual approach lobbying alongside their incumbent partners in broader industry bodies, and as members of the UKHFCA which called for a higher rate of 17.5p/KWh specifically for fuel cell mCHP (justified on the basis of the higher efficiencies of fuel cell driven mCHP; UKHFCA, 2011). However, given the wider commercial consensus the broader based associations were able to articulate, it was their proposals that were subsequently adopted for future feed-in-tariff bands (DECC, 2012b; DECC, 2012c). While HFCs continued to qualify for tariff support they received no additional support beyond that available for other mCHP technologies.

The desire to 'speak with one voice' in lobbying over energy system regulation was expressed in interviews with industry association members and representatives, as deriving both from the interpretations of HFC community actors themselves, and requests from civil servants for clearer views of the needs of industry in relation to particular challenges. If we are to accept this logic, the

⁷ The consultation documents had proposed a rise from 10 to 12p/KWh for mCHP

⁸ Banding of export payments would likely benefit fossil fuel driven fuel cell and stirling engine CHP technologies due to their capacity for reliable peak time export, something photovoltaic electricity generation cannot guarantee.

failure of the UKHFCA to make its case in the above consultation is attributable to its failing to articulate a broader consensus around feed in tariffs beyond the relatively narrow band of HFC community actors that currently comprise its membership. The CHPA and MicroPower Council were able to respond in systemic terms across a range of CHP technologies but UKHFCA's response focused solely on the relatively narrow benefits of HFCs. This is not to say UKHFCA's strategy has been static. In interviews with members and officials, and examination its publications (and those of its precursors the UK Hydrogen Association and Fuel Cells UK); analysis found a clear shift in narrative emphasis away from an earlier narratives of an emergent 'hydrogen economy', to perspectives closer to those of more application or sectoral industry associations. Fuel Cell UK's (2005) Development and Deployment Roadmap played heavily on 'the hydrogen economy' as a metaphor positioning HFCs as a dominant vector across the energy system, UKHFCA's (2012) Manifesto makes no mention of the hydrogen economy at all, preferring to focus on distinct commercial sectors within the broader energy system. This shift in discourse is reflected in the organisations' set piece documentation as well as the association's select committee evidence, contributions to parliamentary events and position papers (Hayter, 2014; PRASEG, 2013; UKHFCA, n.d). Across these texts and in interview narratives, we see a clear shift in lobbying strategy from raising awareness of HFCs benefits as an energy technology, to one based on a more sophisticated interpretation of the UK policy architecture and institutional logics favouring more commercially oriented representations, speaking to specific sectors within established energy systems and markets.

To briefly summarise, HFC community actors were keen to emphasise the objectivity of the evidence they produce for lobbying purposes. Many have gone to considerable lengths in forming partnerships; hiring consultants; joining associations; conducting and publishing research, in order to rationalise the claims they make for sympathetic regulatory reform and incentive provision for HFC innovation and commercialisation. This section has not sought to dispute the techno-scientific rigor of this work but rather to illustrate how actors pre-existing competencies and interpretations of

context shape the objective criteria on which they base their claims. In seeking to collectivise their voices via industry associations, commercial actors seek additional authority in their lobbying efforts, sacrificing technological specificity for the capacity to speak to the interests of the wider energy system and larger commercial sectors within it. Given the reluctance of UK policy actors to be seen to 'pick winners' between low carbon technologies, it is unsurprising this strategy appears to have been more successful in the case of the 2011 DECC consultation. This is not to say the UKHFC is an irrelevance. While sector (as opposed to technology) specific industry associations appeared more influential in consultation outcomes and some interview narratives, the UKHFC retains an important role in keeping HFCs on the agenda of policy actors and as a key consultee for public bodies designing HFC innovation programmes. Moreover in the shifting narratives of the UKHFC regarding the role for HFC technologies, we see an increasing awareness among HFC community actors of the broader institutional landscape they seek to influence. The shift to identifying commercial sectors within existing energy regimes reflects a more finely grained interpretation of this institutional architecture, and an effort to adopt its logics in lobbying activity. As such, while we may suggest that contextual interpretations shape actors' criteria for evidence generation and lobbying strategies, such interpretations are not set in stone. As HFC community actors engage with policy actors and institutions, their interpretations and constructions adapt to them.

IV. Summary

This chapter has explored a range of strategic practices through which the HFC community constitutes itself as a policy community and, sought to provide a sketch of that community as constituted through strategic interactions that are shaped by logics of commercialisation and partnership. Although these interactions overlap with and are shaped by the wider institutional architecture for HFC innovation governance, they are also specific to the contextualised interpretations of competence, context and position of the actors involved.

While the confines of the study precluded a detailed examination of every strategic practice in detail, the analysis presented has sought to illustrate how imbalances in position affect: the various presentational strategies of actors attending conferences; the unequal partnership relations realised in project consortia; actor interpretations of, and strategies in project planning and funding allocation meetings; the agreement of objective criteria in individual and collective evidence production and lobbying practices. As such it characterises the HFC community as a complex field of power relations within which actor interpretations and strategy are shaped by expectations of current and future regulatory contexts, and of the legitimate forms of strategizing and participation permitted within the confines of different practices and institutions for HFC innovation governance. The practices discussed here are not the result of preconceived ideas about what innovation governance should look like. They are drawn from actor narratives and texts which specified key sites of interaction with policy actors and other members of the HFC community. Some analytic refinement has been required in communicating these findings. Not all participants and HFC community members would agree with every juxtaposition or strategic comparison. Many would dispute the conflation between research or evidence production and lobbying, or the distinction between project participation and planning, and indeed there are significant interdependencies and feedback loops between the two.

However, given the nature of the study and the constraints of academic writing it would never have been possible to capture each and every strategic position adopted within the broader HFC community. Some means were required to distinguish and speak to divergent sets of strategic practice and relation. While some subtleties have inevitably been lost in the world making description provided in this chapter, it characterises to the best of the analysts' ability; the broad range of practices HFC community actors see as relevant to their strategic interactions, together with

the key relations and power dynamics which characterise them. In so doing, the analysis has sought to foreground the means by which nominally open and consensus based forms of partnership in HFC innovation governance, have often acted to entrench a privileging of commercial competence over the techno-scientific knowledge of research institutes; incumbents over pre-commercial actors; and pre-commercial actors over their early mover counterparts. This is not to say that actors lower down the categorical hierarchy of HFC innovation governance have been passive in accepting their position. While the overwhelming majority of narratives examined in the study accepted, at least tacitly, the categorical positions allocated to them, strategies of thought leadership; partnering; strategic engagement in funding allocation and project applications, all comprised key means for actors to compensate for their weak positions in innovation governance.

10. DISCUSSION & CONCLUSIONS

I. Methodological Reflections, Limitations and Future Work

The preceding three chapters have sought to provide an actor centred constructivist account of the HFC community outlining three distinct but interrelated phenomena; the competencies and contextualised interpretations through which actors identify interests in HFC technologies; the institutional configurations which shape these interpretations and guide collective action, and finally; the strategic practices through which collaboration, deliberation and social learning take place within it. In so doing this thesis has made a number of contributions to our knowledge of HFC innovation governance, specifying; the key actors present within it; the institutional processes and ideas shaping its development, and the strategic practices through which it is being constructed. Before shifting to a longer discussion of these findings, it is worth pausing to note a number of limitations to this study, in particular the extent to which the account provided may be a product of the methodology it self.

In aiming to study emblematic variation within the UK HFC community, the methodology developed for this study explicitly sought to balance the need for broad coverage with more detailed examination of situated agents' meaningful interpretations. The result could be read as a study that risks falling between two stools, offering neither a detailed microanalysis of interpretation and strategic relations within individual organisations and institutions; nor a statistically representative or generalizable account of innovation governance in the UK writ large. Rather the actor centred constructivist inspired approach adopted, aimed to generate an account of the emblematic variation within the HFC community, grounded in the meaningful interactions of its members. In so doing analysis was reliant on the accounts of actors engaged in overlapping policy processes; cross categorisation and member-checking to develop its typologies and description of the community. To the extent the researcher is confident these reflect credible, reliable accounts this is not overly problematic (Lincoln & Guba, 1985; Schwartz-Shea, 2006). However the strategy of sampling

emblematic actors has had an effect on the form of HFC community it has been possible to specify, and more significantly what it has been possible to say about it. These effects form the basis of the following reflections on the study's limitations and recommendations for future research to address them.

Bounding the Case: inclusions, exclusions and the HFC community

Firstly we should note that in adopting involvement in UK policy processes as the bounding criteria for the study, the research effectively excluded organisational actors who might very well take a view on HFC technologies. Given the relative exclusion of NGO's from some partnership activities and the narrow economic and techno-scientific framings of others, the community the research has thus been narrowed to a relatively group of expert actors and policy makers. This narrowness has important implications for the legitimacy and effectiveness of HFC governance which shall be discussed further below. To the extent this narrowness reflected how HFC community actors themselves viewed their strategic context, bounding the community according to those participating in it conforms to standard interpretive principals of working with the concepts and identifications of the members of a given interpretive community (Yanow, 1996; 2000). We should however be aware of the possibility that a range of actors may exist that are excluded from or disengaged with HFC governance processes which have not been captured in this study. More specifically we should note that the HFC community identified in this study is limited to a 'core' community mutually recognised by policy makers, relatively senior academics and staff of industrial firms. Other varieties of organisational actor not taken to be key by this community, and individuals working lower down organisational hierarchies, may nevertheless consider themselves members of the HFC community. These actors may interpret HFCs in very different ways to the community identified in this study. As such, this thesis can only claim to speak to an HFC community insofar as this community is limited to those engaged in current governance processes.

Given research in STS and environmental policy has shown the potential for latent policy networks, to present significant opposition (Shackley et al., 2005; Toke & Marsh, 2003), delaying deployment and even contributing to the transformation of narrow policy communities; this limitation to the study is potentially significant. Future work should thus aim to identify the full range of potential stakeholder groups in HFC technologies currently excluded from innovation policy making. Recent work by Boucher & Gough (2012) has sought to achieve similar outcomes in relation to CCS technologies, surveying the ethical positions adopted in the discourse of environmental NGO's. Such a review on HFCs may provide an initial starting point for identifying NGO's and potentially wider media, publics and consumer groups that may take a position on HFC innovation governance as the technology approaches deployment. This would provide a valuable counterpoint to this study and provide a bridge between it and the public perceptions research already underway into the HFCs (Cherryman, et al., 2009; Ricci, et al., 2010; Sherry-Brennan, et al., 2010).

Given the stated focus of this thesis on the UK HFC community, the inclusion and prominence given to the FCHJU in its research and conclusions is also open to question. As an institution subject to formal control entirely separate from the broader UK policy architecture for HFC innovation, its inclusion in the study may seem difficult to justify. Indeed at the outset of the research, there were no plans to include the FCHJU in the final study. However, the snowball sampling approach adopted and frequent referrals to the FCHJU in interviews made its inclusion a necessity. In shaping expectations of HFC market introduction via its demonstration projects and funding activities, the impact of the FCHJU on UK based HFC community actors is significant. Moreover without FCHJU funding, many UK based companies; projects and partnerships may never have emerged and, had they done so, they may have taken very different forms. While it would have been desirable to move upwards from the FCHJU to higher scales of European governance, given the EU's fragmented intra-state structure and the vastly expanded range of industrial actors involved at this level, the scale of

this task would have been far greater than that of the UK HFC community. As such, the study of EU wide HFC innovation governance is a task suited to a different project; most likely operating at a higher level of analysis than actors and their strategies, at least in the first instance.

Breadth & Depth: correlation, interpretation, interests and values

Related to the above concerns, the second limitation of this study lies in the level and variety of analysis to which the data collected lends itself. Specifically, the level of abstraction implied by the analytic category 'emblematic variation' is somewhat more abstract than some interpretivist researchers may desire, while also lacking in the capacity for statistical validation a more quantitatively inspired approach may have provided. As a result it is conceivable the research may have overemphasised or overlooked important interpretive nuances and correlations within and between the actors; institutions and strategic practices it examines. Moreover, while the study points to the roles of ideas and interest, it struggles to characterise the process through which they interact in specific contexts, and; the relative importance of each in shaping organisational decisions and strategies. While the actor centred constructivist approach adopted has been useful in specifying the emblematic variation of actors within the HFC community, to some extent its capacity to explain this variation in terms of meanings and readings of organisational and institutional contexts leaves some gaps. Why is it some research institute actors spin out pre-commercial firms while others do not? Why have some incumbent firms spent years and even decades developing long running HFC RD&D programmes and competencies, while others in the same sector have not? What differences between pre-commercial and early mover firms lead to their radically divergent interpretations of the energy and resource contexts in which they find themselves?

There are two potential answers to such questions. Firstly, given the multinational and multi-sectoral nature of many HFC community actors, different organisations may identify different interests due to

different historical experiences of markets and regulation in their home markets. Focussing on these interests would require a study casting its net wider and focussing on a narrower range of variables to test the interactions between ideas and more specific features of market and regulatory context. The second potential explanation may be that, for some actors at least, the interpretation of contexts and identification of interests is not the result of rationalistic calculation; but rather results from some deeper rooted concept of identity and values. Examining such processes would thus necessitate more contextualised focus on the experiences and ideas of a narrower group of actors.

One potential explanation for divergences in why actors of the same or similar types identify different interests may lie in historical and regulatory features in the home markets of HFC community actors. In focusing on meaningful relations within the relatively narrow polity of the UK HFC community, some of the international aspects of HFC innovation and the global energy and technology markets surrounding them have been sacrificed in favour of depth. In so far as this made possible the identification of emblematic forms of actor variation within the HFC community, this depth may facilitate future studies looking to these international regulatory frameworks as part of broader, economically informed survey research. Conducted under a more explicitly material-semiotic ontology (cf. Jessop, 2010), such a study would pay greater attention to international regulatory landscapes, energy markets and their effects upon actors ideas and interpretations of economic interests. Such an approach may be capable of capturing historical regulatory effects on the competencies displayed by different forms of actor within the HFC community that this more time-bounded and localised study has been unable to capture. To the extent such competencies are identified in this thesis as shaping interests, this marks a potential gap in the account it provides.

Conversely, a more contextually based study would also have provided additional insight into the interactions between ideas and interests albeit across a narrower range of actors or institutions. Working across multiple institutions and partnerships, all aiming towards the generation of industrial consensus, the research at times struggled to scratch the surface of consensus documents and decisions. The complaints of a minority of research institute and early mover actors suggested higher levels of controversy than accounts provided in official documents and incumbent interviews. However the lack of access to open debate focussed on a single policy decision or partnership process made it difficult for the study to track comprehensively the ideas and interests at play throughout. Had the decision been taken to focus on a single case of governance, for example a particular partnership; project or public body, the research may have revealed greater levels of disagreement or 'institutionalised knowledge conflict' (Hisschemöller & Bode, 2011), than was possible in taking the HFC community as a whole as the phenomena under study.

Such a study, ideally conducted longitudinally would have further clarified how pre-existing actor competencies and contexts informed their interpretations of and interests in particular innovation trajectories; as well as if and how such interpretations shifted during collaborative processes. However, given the lack of pre-existing knowledge of the HFC community present in the literature and the absence of a single institutional structure mirroring Dutch innovation governance practices, setting the scope of the study broadly was not an unreasonable starting point to adopt. While the researcher can now confidently point to the FCHJU working groups and UK H₂ Mobility as key points at which innovation priorities; infrastructure; RD&D and regulatory agendas are set, this was by no means clear at the outset of the research. Indeed UK H₂ Mobility only came into being in 2012, as the researcher was entering the field. As such more detailed studies of these sites represent a key area for future research. Given the tendency for such activities to be governed by various confidentiality

and non-disclosure agreements, it may be advisable for such a project to seek to work within the evaluation and reporting procedures of the partnership or public body itself in order to gain access.

Moreover a more contextually focused account would have facilitated additional exploration of the role of values and identity in shaping actor interpretations of ideas and interest. Analysis touched at times on claims to values of objectivity and environmental concern which appeared tied to the identities of some early mover and research institute actors. Given the research focus on identifying emblematic variation, the reasons for this division were not examined in great depth or detail beyond their relationships to the wider institutional architectures, ideational and market landscapes in which they emerged. Recent work in practice theory, on actors 'investment in practices', points to a process of mutual structuration through which the development of competencies and psychosocial attachments emerge together, shaping interpretations of interest and rational decision processes at the level of individual and communal experience (Adam & Groves, 2011; Groves, et al., Forthcoming; Hards, 2011). Although this thesis has selectively borrowed some analytic concepts from practice theory, in operating at the level of emblematic variation in actors inter-subjective relations, it has not afforded the space to explore possibilities for synthesising its more psychosocial insights with constructivist policy analysis. However to the extent they may shed further light on why particular actors with particular competencies emphasise particular interests and value positions, such a synthesis may constitute a valuable direction for future research to take.

The suggestion that either psycho-social study at the level of individual or organisation; or larger scale survey research might offer additional insights into the actors, interests and values of the HFC community, does not mean that the study presented in this thesis is inherently flawed. In its aim to identify emblematic variation between key actor types, the study always aimed at providing a level of

analysis between the systems and deep interpretivist levels. In highlighting research institutes; pre-commercial; early mover; cautious and enthusiastic incumbent actors; as well as the broader policy architecture and range of strategic practices included within the HFC community, this thesis has broadly achieved its goals. While it does not claim to be the definitive account of the HFC community, it provides a grounding in case knowledge outlining key actor types and practices taken by HFC community members themselves to be vital to their work. Work proceeding on the basis of this account should however note that, given the contextual specificity of the HFC community, care must be taken when translating its findings to other fields of innovation and policy making. Moreover, as an initial scoping account aiming to characterise the community, this thesis necessitated compromises between representative breadth and interpretive depth. Its account should thus not be read as a naturalistic or representative study capturing the entire HFC community as it exists in reality, but rather as narrative (Creswell & Miller, 2000; Flyvbjerg, 2011;) or articulation (Glynnos & Howarth, 2007). Grounded in credible, systematic and rigorous research, it nevertheless represents a theoretically refined simplification of the irreducible complexity of actors, ideas and meaningful relations encountered in research.

II. Actors and Membership of the HFC Community

A key finding illustrated in the preceding chapters has been the typological description of the HFC community as a collection of actors whose ideas and interests are shaped by meaningful interpretations of their competencies and contexts. The thesis has sketched the emerging relationships between actors of different types, and those between previously distinct application sectors in domestic heating; electricity; and transport. In the latter case the research has pointed to an uneven process of integration between these sectors which are at times treated as distinct areas for RD&D, and at others requiring integration for the development of complete HFC energy systems. Given the sheer range of actors and practices examined, and the ongoing evolution of this integrative process, characterising it fully proves challenging. However, in the sense that the research initially set

out with relatively little idea of the actors involved in the HFC community, it has been successful in identifying the emblematic variation or key types of actor involved.

Despite the focus of the research on three distinct cases of HFC technology in domestic heating, energy, and transport, a notable finding has been significant commonalities between actors working across these applications. In particular actors working within and across sectors interpret their interests in HFCs in very similar ways, through the lens of their own material and ideational competencies; and their organisational; regulatory and market contexts. While policy actors stand ready to assist the HFC community, they do not identify as members of it. In so far as these actors can be said to have clearly identifiable interests in relation to HFCs, they are located at the level of policy paradigms and associated logics which guide the approaches they deem appropriate to fostering energy innovation more broadly. The key actors within the HFC community conversely interpret the technology to be central to their interests. This is not to suggest, in a positivistic fashion that there is some real, necessary relationship between HFCs and the wellbeing of these actors. Rather they are shaped by experience of context; the competencies at their disposal, and through strategic relations with other actors in the community. Research institutes thus orient themselves to the technology through recourse to their techno-scientific competencies and objectivity, and institutional contexts that privilege energy innovation as an impactful activity. In so doing they identify their interests in HFCs as tied to research funding regimes, and the generation of broader social utilities in the form of renewable, low carbon technologies for the improvement of the environment and energy system. Pre-commercial firms and enthusiastic incumbents interpret their competencies in HFC technologies and existing markets as key strengths looking forward to emergent energy system contexts that are likely to reward low carbon technologies. In so doing they identify their interests in the market opportunities and competitive advantage afforded by their HFC expertise. Early movers conversely view their interests through more radical readings of resource and regulatory landscapes that they believe will constrain human energy systems far more than their

mainstream counterparts will admit. Possessing techno-scientific competencies and identifying freedom in their lack of ties to existing energy regimes, such actors view HFC technologies as a means of radically breaking with resource and energy intensive systems.

In describing these five categories of actor the thesis has characterised, for the first time, the emblematic variation present within the UK HFC community. While the organisational cases examined in documentary research and interviews all corresponded to this typology, the boundaries between types is somewhat porous. Many pre-commercial firms begin life in research institutes before they are spun out as private entities. Similarly there is no clear line between cautious and enthusiastic incumbents. Competence in HFC innovation can be gained and lost over time, and for some cautious actors initial low risk project engagement may well eventually lead to the adoption of a more enthusiastic position in relation to the technology. While some enthusiastic firms such as industrial gas companies are heavily invested in the sector through their existing market interests and competencies, others could divest themselves of HFC involvement at little reputational or financial cost. Given this thesis represents a snapshot of the HFC community over a relatively short period, the movement between enthusiast and cautious incumbent is not something it has been possible to track in great detail. However anecdotally several participants made reference to formerly enthusiastic incumbent firms delaying or abandoning plans for market introduction. Likewise, although early movers are in part defined by their radical interpretations of context, it is possible these smaller firms are simply yet to generate partnerships with incumbents that would necessitate a moderation of their narratives. Considering the strength of opposition to 'vested interests' seen in some early mover narratives, the later move seems unlikely, but without stronger longitudinal data covering the sector, such a question is difficult to answer.

In establishing a framework for categorising actors in the HFC community, this thesis makes a number of theoretical contributions. Firstly it expands upon the niche, regime landscape model offered by conventional accounts of socio-technical transitions (Geels, 2010; Rip & Kemp, 1998; Rotmans, et al., 2001); drawing in constructivist insights on to the importance of ideas and institutions in mediating the interpretation of landscape pressures at niche and regime level. In so doing, it also elaborates the multi-layer perspectives three-fold distinction; distinguishing between early mover and pre-commercial firms at the niche level, and; cautious and enthusiastic incumbents at the regime level, which may be of use to others in the study of alternate innovation communities. Moreover, in drawing on practice theoretical concept of context, competence and meanings as a means of analysing and categorising actor involvement in policy practice, this thesis contributes to our understanding of how and why regime actors seek to extend the lifetime and lock in of their preferred technologies and manage innovation processes to suit their own interests.

Secondly, in developing a typological account of the actors within the HFC community, it becomes apparent just how narrow the community is in terms of the organisational contexts and competencies informing the bulk of its members. During the research process, the documents and relational identifications made by interview participants pointed to a relatively narrowly defined group, drawn predominantly from academia, industry and policy. While initially it was thought this would extend to include NGO's and user groups, this did not prove to be the case. As a policy community, the HFC community has been broadly successful at drawing in 'expert' knowledge. However in doing so from a relatively narrow range of domains it conforms more closely to Rhodes & Marsh's (1992) definition of a homogenous policy community comprising economic and producer interests with shared aims and values, than it does to a more open network. Given the focus given in much of the literature on networked governance and responsible research and innovation on the capacity of public-private networks to democratise decision making and ensure legitimacy (Hajer,

2003; Hoogma, et al., 2002; Schot & Geels, 2008; Sørensen & Torfing, 2009; Torfing, 2007), the absence of a broader range of stakeholders was somewhat surprising.

While policy making in other fields of low-carbon innovation have been similarly characterised by relatively narrow communities with shared aims, goals and ideas about what constitutes appropriate knowledge and governance practice (Stephens, et al., 2011), it is also the case that significant efforts have been undertaken to ensure a wider range of ideas; interests; stakeholders (including publics and NGOs) are incorporated into the innovation process (Gough, et al., 2014; Shackley, et al., 2005; Toke & Marsh, 2003). Moreover, as Toke (2011) argues in the case of renewables, policy support has been underpinned by strong support from a wider community of NGOs and environmental activists allied to the renewables industry. Given that widespread deployment of HFCs is generally considered to require significant and prolonged policy support, and; deployment of potentially contentious infrastructure for H₂, a highly combustible fuel (Ekins, 2010a), this thesis raises questions as to whether the HFC community constitutes a broad enough coalition to secure the eventual roll-out of the technology. Moreover it provides a valuable reminder that, despite multiple articulations of best practice regarding the inclusion of broader social groups in technological innovation (European Commission, 2012; POST, 2001; Schot & Geels, 2008; Willson & Wills, 2004;), innovation governance can still be guided by relatively narrow expert communities.

Sectoral Expertise: Electricity, Heating and Transport

The HFC community constitutes a network of organisations whose interests coincide around HFC technologies. This coincidence results in large part from the fragmented nature of technological competencies in the energy and transport sectors, in which no one organisation possesses the capability to introduce a complete HFC energy system. Be it in domestic heat and power, transport or grid back-up applications, the expertise to introduce these systems lie across different organisations

and in different sectors. Competence in a particular aspect or component of potential HFC energy systems thus comes to form the key membership criteria for the HFC community, and the primary rationale for collaboration within it. The three technology sub-groupings identified as of particular interest for this study, HFCs for electricity; domestic heating and transport, thus come to appear less distinct than initially imagined. Actors with competence in each area are viewed as important in bringing HFCs closer to commercialisation, and they are treated in similar ways by policy actors and institutions. While it is true actors are often involved in distinct projects and strategic practices tied to their distinct application area, these lines are increasingly blurred. In forging links between electricity sector actors and providers of domestic heating or transport technologies, institutions such as OLEV, the FCHJU and UK H2 Mobility are increasingly drawing them together around a shared set of concerns and priorities.

This blurring of lines between energy consuming sectors is a relatively new development. Long foreshadowed by the emergence of fuel scarcity and decarbonisation on the sociotechnical landscapes for electricity; heating and transport, their integration has been made possible by institutional reforms and the more recent emergence of 'smart' grid technologies capable of integrating them. The formation of DECC as a department responsible for 'energy' as a distinct cross-sectoral domain marked an initial move in this direction. The emergent institutional architecture for HFC innovation represents an acceleration of this processes that can be seen in wider government commitments to electrification in domestic heating and transport (DECC, 2011; 2013). To date, the implications of this boundary blurring has been under explored in the literature on UK energy policy. Hitherto, policy making in this sector has been dominated by a relatively narrow band of utility company incumbents, with transport managed under an entirely different department with separate priorities and concerns (Mitchel, 2008; Geels et al., 2012). While this thesis has highlighted a more or less integrative process of collective socialisation and learning between incumbent electricity and

transport sector actors, it is uncertain just how far this integration is likely to proceed. Moreover, we do not know how the UK energy policy regime will adapt to the incorporation of a powerful new industrial interest group in the shape of the automotive sector. This emergent process is of central importance to the emergence of HFC innovation governance and energy policy more broadly and should be a key priority for future research in both fields. Given the overarching focus of this study on emblematic variation across applications, an interesting follow up would be to focus on a single application such as domestic heating and examine the relations and process by which actors from other sectors such as builders and boiler manufacturers come to enter into it. At present this process seems to be farthest along in the transport sector. Given that battery technologies carry similar implications for electricity demand and grid management to those of HFCs, a study focused on the entrance of energy system actors into automotive innovation, possibly centred on a partnership such as UK H2 Mobility may provide a finer grained analysis of these emergent cross-sectoral relations than has been possible in this study.

III. Institutions & the Logic of Commercialisation

In discussing the institutional architecture into which the HFC community is emerging, Chapter 7 described a polycentric collection of formal institutions engaged in HFC governance practices. In particular four varieties of formal institution were identified; government departments; public bodies; partnerships and projects. In line with the dual goals of supporting private sector regulation, while maintaining a distance between the centralised state and the selection of emergent technologies, these institutions are distinguished by their relative proximity to and engagement with private sector actors. Thus central government departments have tended to remain distant from the day-to-day processes of deciding innovation policy priorities. While departments retain a role in setting regulatory criteria and incentive systems, their involvement with HFC community actors tend to be conducted at a distance via formal consultation procedures covering a broad range of technologies. At this level interaction does not take place between departments and HFC community

actors, but rather with broader coalitions of technology interests. However, at the level of providing support for innovation, a range of additional institutions have been established. A number of arms-length bodies such as the EPSRC; Carbon Trust and TSB have taken an interest in HFCs within their broader remits for supporting the UK energy innovation system. Charged with the design of RD&D support programmes, these bodies draw many of their staff and funding priorities from the industrial sectors they serve. In so doing their work is shaped by a commercial logic which positions experts in research institutes and industrial organisations as the most appropriate groups for deciding on RD&D priorities. In so doing, institutions for HFC RD&D have operated as a means of delegating authority over RD&D priorities; funding decisions; and policy delivery to industrial actors.

Across these institutions, we see a picture in which the higher the level of technological specificity, the lesser the role policy actors deem appropriate for themselves to have. From networked policy making processes based around public bodies, to industry led deliberations over partnership activities, a picture emerges in which energy innovation is emerging as a more significant aspect of policy- albeit aligned to overarching goals of market introduction. In seeking to explain this institutional architecture, this thesis drew attention to a logic of commercialisation. Expressed in metaphors such as 'chicken and egg problems' and 'the valley of death', this logic partially operates to authorise state intervention in private sector innovation activities previously considered the appropriate domain of the market. However, such activities remain bounded by the overarching goal of commercial introduction which specifies the generation of profitable, private sector produced HFC technologies as the ultimate ends to be achieved. As such this logic serves both to legitimise and constrain state intervention in energy innovation systems. Policy actors in public bodies and public private partnerships are permitted to facilitate and fund, while not encroaching into specific technological decision making or picking winners between emergent technology options.

The logic of commercialisation represents a confluence of ideas and interpretations regarding the appropriate means of pursuing HFC innovation within the confines of UK and European energy policy. Three central assumptions underpin this logic;

- 1) HFCs represent a promising and marketable technology for supporting goals of economic growth and decarbonisation.
- 2) The market and private businesses are the most appropriate mechanisms for delivering and deploying HFC products and systems.
- 3) Given the existence of market failures, a degree of state support is necessary and permissible to facilitate the commercial roll-out of HFC technologies and systems.

While the logic of commercialisation can thus be read as a relatively simple formula, it draws on paradigmatic ideas of energy market liberalisation and imperatives to decarbonise energy production and consumption that exist at higher orders of policy discourse. As such the logic of commercialisation functions as an ideational lens or grammar through which instruments for HFC innovation policy are designed, interpreted and enacted. We see this reflected in policy actors' commitments to professional networking and ideas of customer service, through which they seek to assess funding priorities according to the needs of the communities they serve. We see it also in the programmatic structure of the FCHJU; the remits and funding criteria for individual public bodies such as the EPSRC; Carbon Trust and TSB. In each instance RD&D goals are designed to channel breakthrough research and emergent technologies further across 'the valley of death' towards commercial realisation. At the same time however, responding to 'chicken and egg' metaphors for the commercialisation process, such institutions seek to embed not only a commercial focus but also a collaborative one. Bringing together networks of pre-commercial and incumbent firms in different sectors, such institutions seek to establish patterns of cross sectoral knowledge exchange, learning and partnership to bridge the gaps in competencies the commercialisation of HFC requires.

The logic of commercialisation thus carries power in a number of ways, shaping; what policy actors perceive as appropriate strategies for meeting their remits; the institutional structures and meta-governance rules for public private partnerships and RD&D networks. In the first instance this logic provides a rationale and legitimacy for the categorical distinctions and exclusions underpinning the hierarchical organisation of the HFC community. Secondly, in establishing an expectation that the state will support the roll-out of HFC technologies, policy actors and institutions have a role in shaping the contextual interpretations of HFC community actors. In making funds available and adding their authority to HFC projects and partnerships, policy seeks to draw in desired incumbents that may otherwise be cautious of HFC technologies, and, shape the research and evidence producing actions of research institute and pre-commercial firms. Thirdly, in shaping the interpretations of civil servants and HFC community actors engaged in HFC innovation governance, this logic serves to de-politicise its conduct by closing off alternate roots of discussion.

Paradigms and De-politicisation

In identifying logics of commercialisation as the key principal of HFC innovation governance, this thesis offers valuable clarification of what is going on within the paradigmatic bricolage characterising contemporary UK energy policy (Kern et al., 2014). More specifically it provides an account of how partially contradictory policy ideas of market liberalisation; decarbonisation and; cost reduction, are being interpreted and enacted at lower orders of policy making and delivery, in the day to day governance of energy innovation. Decarbonisation imperatives provide important legitimisation for policy institutions limited interventions into innovation processes usually left to the market. At the same time, market liberalisation era ideas continue to play a role in the scepticism departments and public bodies display over the states capacity to arbitrate between competing technologies, and their corresponding deference to actors with commercial and techno-scientific

competencies. Added to this the resurgence of industrial policy under the rubric of low-carbon innovation, ties energy innovation to economic goals of economic growth and job creation. The logic of commercialisation refers to the fusing of these three paradigmatic layers into the ideas, routines and structures of policy actors and institutions.

This layering is not without its frictions and contradictions. As was seen in examinations of funding deliberations; evidence creation and lobbying, decisions are often taken on the basis of consensus between industry actors present at the meeting; the largest alliances of industry bodies; or the relatively narrow research processes framed by incumbents. While decarbonisation potential is often a consideration in these practices, it appears secondary at best, and we rarely see actors engaged in such practices attempt to compare such potential against alternate HFC energy systems. Similarly the commitment to industrial consensus in funding deliberations and consultations sits uneasily besides competition in desires for future markets and current funding allocation practices. This leads to some interesting tensions between professed openness to new innovations and the realities of incumbent power, it may well be a narrow selection of HFC technologies that are granted the opportunity to compete in future markets.

To the extent this thesis identifies incumbents as privileged within HFC innovation governance, it serves to corroborate Winskel & Radcliffe's (2014) description of an incumbent led accelerated energy innovation system operating in the UK. Beyond this it raises interesting questions as to the quality of governance this represents. In Wood's (2015) recent account of puzzling and powering within policy paradigms, he draws a distinction between social learning at second order policy change, and de-politicisation at the level of the paradigm. The former is thus situated as opening up potential options, while the latter seeks to enact a discursive closure in which wider contingencies

are closed off to discussion. However, in the case of the HFC community we see de-politicisation enacted at both levels. In restricting membership to relatively narrow coalitions of actors around specific techno-scientific challenges and funding prioritisation process, the meta-governance of the HFC community carries many hallmarks of technocratic social learning. Claims of objectivity, evidence production and expert consensus are all suggestive of this quality of governance. At the same this technocratic mode de-politicises the power of incumbents and the contingency of their technological preferences on existing market competencies. Collaborative learning in this sense comes to mask the exercise of incumbent power. In failing to challenge the position of incumbents from established policy regimes, the community participating HFC innovation governance takes the form of Eagleton-Price's (2014) 'governance in the spirit of capitalism'. While not designed for the strict benefit of any single incumbent party, it serves to reproduce the assumptions and technological configurations on which their position depends. To the extent such power may override the relative benefits of alternative technologies in terms of decarbonisation potential, this raises significant questions over the appropriateness of prominence given to incumbents in innovation policy processes, and the commercial logic underpinning their position.

Meta-Governance and Sustainability Transitions

Mirroring other instances of networked innovation policy development (Smith & Kern, 2009; Winskel & Radcliffe, 2014), the institutional architecture for HFC innovation governance has been developed in anticipation of high levels of incumbent participation and leadership. While some of the 'customer focussed' means of developing understanding employed by public body civil servants suggest recognition that some pre-commercial actors may prefer a more flexible means of engaging in governance processes, this was not the case at the FCHJU level. Nor do we see it in the consultation strategies employed by departments or the membership criteria of partnerships such as UK H₂ Mobility. The reason for this unevenness lies in the contradiction between partnership and market roll-out at the heart of the logics driving HFC innovation governance, and creates the possibility for

differential interpretation of the relative importance of non-incumbent technologies and visions. While in some cases it may allow for the incorporation of a broad range of pre-commercial actors and techno-scientific experts, in others it enacts a hierarchical categorisation between different forms of organisational expert within which industrial actors tend to be privileged over research institutes. In such instances, the overarching goal of market roll-out leads institutions to look to the established size and reach of incumbents as a means of speeding up deployment at the expense of more radical innovations and visions of energy system transformation.

The logic of commercialisation thus comes to form the key meta-governing principal underpinning HFC innovation governance in the UK and at the FCHJU. This is not meta-governance of the variety favoured by some of the more normative accounts of network governance, whereby the framing and agendas are left open to the widest possible range of stakeholder groups (Hudson, et al., 2007; Sørensen & Torfing, 2009). Rather, commercial logics frame HFC innovation as an activity best suited to organisations with competencies in techno-scientific research and product development, often favouring the visions and preferred technological trajectories of the incumbent actors deemed most capable of delivering them. It is this mechanism which makes possible the relatively exclusive nature of the HFC community and the narrow range of actors we find within it.

Similarly in promoting expectations of future commercial viability for HFCs, and drawing together incumbent; pre-commercial and policy actors in collaborative deliberation over energy innovation priorities, the commercial logic of HFC innovation governance bears some similarities to the learning based model of socio-transitions advocated by innovation theorists (Geels, 2010; Rip & Kemp, 1998; Rotmans, et al., 2001). UK H₂ Mobility's collaborative research and planning; attempts by the FCHJU and UK public bodies to encourage supply chain links between pre-commercial and incumbent

actors, and; cross sectoral project participation all point in similar directions. Notwithstanding its similarities, the commercial logic shaping HFC innovation departs from transitions theory recommendations in its reliance on incumbent actors at the expense of greater incorporation of the technologies and visions of more radical niche players. Thus while incumbent visions of mass market introduction of HFCs remain contested by early movers, and some academic studies (Ekins & Hughes, 2010b; Hardman, et al., 2013), such actors are afforded far lower levels of legitimacy in innovation governance processes. Given the history of disruptive innovation and past socio-technical transitions, in which incumbents remain locked-in to particular technologies and unable to compete with emergent niche producers (Christensen, 1997; Geels, 2002), the position they are accorded within innovation policy processes is at the very least questionable.

To the extent that experience in the Netherlands, where the institutionalisation of transitions theory recommendations did not have the desired effects in terms of fostering radical niche innovation (Hisschemöller & Bode, 2011; Smith & Kern, 2009; Kemp, et al., 2007), this may not ultimately have mattered. However if both transitions management approaches, and less formalised attempts at policy reform seen in the UK have difficulty incorporating and empowering expertise from outside established regime networks, this raises significant questions for innovation policy and other forms of networked governance. If primacy is not to be granted on the basis of established reputation and competence in existing markets; how are policy makers to judge the expertise of those they seek leadership from? Here the normative recommendations of deliberative approaches to ecological modernisation, and some of the more inclusive iterations of innovation theory may offer some recommendations in their insistence on recruiting and empowering broader ranges of niche actors and societal stakeholders, beyond established energy policy regimes (Willsdon & Wills, 2004; Dryzek, 2005; Schot & Geels, 2008; Lehtonen & Kern, 2009). However, if the Dutch example of transitions management is to be used as a yardstick for recommendations, this approach still has limits (Smith,

et al., 2005; Smith & Kern, 2009). More significant changes would require a more fundamental challenge to the current paradigm for UK energy innovation, and a concerted challenge to the logics of commercialisation which have tended to privilege incumbent expertise at the expense of others. Such a challenge would likely require the mobilisation of a broad coalition of civil society groups and environmental NGO's allied to pre-commercial and early mover technologies.

Early mover coalitions such as that we see in RiverSimple's ownership structure granting representation to community and environmental interest groups, points to a novel development in this arena. However it is unclear whether this case or another like it is capable of, or even interested in mobilising a broad coalition for paradigmatic change. However the space the existing regime for HFC innovation provide for the support of these smaller players, and notional commitments to public engagement as a form of pre-market activity leaves open a gap that may be exploited by these more radical actors. Given the focus of this thesis on characterising the HFC community via emblematic variation, examining the historical development and trajectory of policy within its sub-groupings is beyond its scope. However, future process tracing studies analysing where incumbent led innovation is leading us; if and how more radical niche based coalitions are emerging should be priorities for future research. Process tracing studies of these phenomena may offer valuable insights into the trajectory of the existing regime for HFC innovation governance, and whether further paradigmatic contestation might be expected in the coming years.

IV. Practices and Strategies

In suggesting the HFC community is structured to the interests of incumbents, this thesis does not mean to claim other actor types are entirely passive, many enthusiastically pursue strategies of partnering with larger incumbents as a means of obtaining additional funding, investment and reputational capital. Where institutional structures for policy or funding deliberation prove

cumbersome, pre-commercial actors have engaged strategically, looking to the meetings and industry associations that offer greatest opportunity for shaping relevant policy priorities. While at times presentational strategies of thought leadership are invoked, pre-commercial actors and HFC specific industry associations have been learning to tailor their rhetoric to the language and priorities of current regime actors, shifting from earlier discourses centred on 'the hydrogen economy', to one of energy system optimisation. Early movers, while limited in number represent the point at which the relatively narrow HFC policy community becomes a more heterogeneous network. Less willing to moderate their discourse and sceptical of their capacity to shape innovation priorities, they limit their strategic interventions to bidding for funds at the correct times, forming limited partnerships where possible in the hope their technological niche will take off.

Despite these strategic differences, across the HFC community we have seen the emergence of a range of intersubjectively recognised practices and procedures, designed to facilitate deliberation and decision making over the form future HFC energy systems should take and the specific technological priorities that should be pursued. Conferences and networking events provide relatively open fora for a range of actors from different technological and sectoral backgrounds to; exchange views and visions for HFC technologies; make the case for their preferred technologies; and develop relationships with potential project collaborators. As such they can be read as bridging points between niche and regime actors, allowing them to identify others with compatible visions and competencies with whom to work. Projects conversely offer space for technological development; testing and learning, through which common product and system designs can emerge. However unlike conferences, project participation is less open. Structured by competitive bidding processes and often shaped by the technological requirements and milestones of incumbents, their orientation towards commercialisation also operates as a means of filtering niche technologies and actors for those most amenable to incumbent interests. Similarly the formal and informal network

and institutional structures developed to deliberate upon and allocate funding priorities appear operate both to generate collective priorities and programmes for RD&D funding, while in some instances, narrowing collaboration to those actors most able to participate. Finally although a range of discursive strategies are visible in relation to evidence creation and lobbying practices, there is widespread agreement that the production of evidence provides the primary means of influencing questions of market structure and regulation when it comes to emergent HFC technologies. While some of these practices are subject to exclusionary commercial logics which operate to limit the range of participation and shape actors strategic engagement within them, they none-the-less constitute a means of generating collectively agreed priorities and enactments of HFC innovation governance.

In identifying these strategic practices this thesis sheds light on how, in the absence of a formalised transitions based approach to energy innovation; the UK and EU have none -the-less engaged a broad range of industrial and research actors in HFC innovation governance. While this process has not led to the construction of a single overarching policy discourse, or a common set of institutional rules and procedures; it has allowed for the development of common projects and facilitated the generation of consensus based agreements over specific innovation funding priorities. However, we should be wary of overstating the potential for such strategic interactions to generate more significant policy outcomes beyond the relatively narrow and technocratic realms of RD&D priorities. In accepting overarching logics of commercialisation and partnership, HFC community members accept an incremental approach to energy system transformation, led by large incumbents. Given the disincentives to challenging such visions, pre-commercial and research institute actors have instead opted to modify the claims they make, constructing HFC technologies as artefacts for energy system optimisation. In so doing they forfeit the opportunity to articulate broader visions of sustainable hydrogen economies. Whereas advocates of nuclear or solar energy have been able to

articulate clear discourses of securitisation and decarbonisation (Scrace & Ockwell, 2009; Toke, 2011; 2013), the HFC community is essentially de-politicised, limiting discussion to relatively narrow technical questions asked by public bodies and government departments. This is not to say such questions are irrelevant. However, in lacking an overarching narrative for the benefit of HFC technologies, the HFC community limits its potential for developing alliances with NGOs and other normative entrepreneurs that might facilitate more significant policy learning and adaptation (Börzel & Risse, 2003). This issue is compounded by the relative lack of interest within the community and public-private partnerships for attracting the participation of NGO actors. The result is a policy community active at the level of funding and RD&D deliberation, but lacking in significant recognition as a priority for central government.

Agency Centred Constructivism in Policy Networks

In focusing on logics and actor strategies within the HFC community, this thesis has sought to locate its account at the level of rational action within a particular set of ideational and institutional structures (Saurugger, 2013). In so doing, it has identified the ongoing process of HFC innovation governance as permitting a degree of strategic agency, constrained by overarching logics of commercialisation and partnership that limit the range of participatory and discursive options available. What we see in this picture is a form of bounded or cognitive rationality (Boudon, 2003), in which ideas; values and beliefs inform decision making in addition to narrower considerations of contextual position; costs and benefits. Actors in the HFC community adopt strategies based on meaningful, and on occasion value laden interpretations of their capabilities and institutional contexts. For some, strategies reflect consequentialist attempts to realise opportunities or minimise risks. For others, the realisation of scientific objectivity; environmental public goods; or the disruption and transformation of systems perceived as unsustainable, reflect the ultimate goal. For policy actors and institutions, logics of appropriateness derived from ideas of 'customer service' and

commercialisation seem to outweigh consequentialist concerns relating to their own individual or institutional interests (March & Olsen, 2004; Saurugger, 2013).

In elucidating these nuances, this thesis has provided a valuable illustration of the value of actor-centred constructivist research (Saurugger, 2013), specifically its ability to account for both material interests and ideas in guiding the strategic interactions that constitute policy processes. The structural position accorded to incumbents in this account stems, not only from the widely held belief in their expertise and power, but also from the capacities at their disposal for large scale participation in HFC activities, and the economic capital they bring to collaborative RD&D activities. To the degree incumbents reputations operate to confer investor confidence and credibility on their pre-commercial allies, there is an economic link tying together these actors' interests and socio-technical visions. While early movers ideationally opposed to incumbent visions can and do decline to collaborate with them, such a position comes at the price of reduced investment and influence in governance processes. At the same time the privileged position incumbents are afforded within policy institutions and processes, is a product of higher order ideas and policy paradigms which assume these actors to be best positioned to deliver goals of economic growth; efficient energy systems and decarbonisation. Moreover the belief in decarbonisation as a desirable objective, while grounded in substantial evidence and scientific consensus, is more often deployed by HFC community members as an idea to legitimise their central focus of generating marketable products and systems.

While this thesis does not claim to have resolved debates regarding the role of interests and ideas in policy making, in pointing to the role of situated interpretation of existing competencies and contexts informing actors strategic interests, it contributes to the ongoing development of actor centred

constructivist thinking (Saurugger, 2013). Moreover it illustrates how an actor centred constructivist approach can act as a remedy to the relatively structured approach to agency assumed in much of innovation and sustainable transitions theory (Rip & Kemp, 1998; Brugge, et al., 2005; Kemp, et al., 2007), and the over-emphasis given to discourse and deliberation in some of the ecological modernisation and networked governance literature (Hajer & Wagenaar, 2003; Christoff, 1996; Sørensen & Torfing, 2009). This is not to say these alternate approaches are inherently flawed. Examination of the economics and infrastructures underpinning existing and future regimes are still necessary to tracing possibilities for systematic reconfigurations of existing socio-technical regimes, and may well yield further insights into the interests of HFC community actors. Likewise a focus on the shifting discourse of the HFC community, and the deliberative fora in which its members meet may offer more finely grained analyses of the strategies and power relations between different coalitions of actors. However, in providing a framework for sketching the emblematic variation between the ideas and interests of HFC community members, the actor centred constructivist account provided in this thesis provides an additional analytic frame that may prove valuable for furthering and synthesising such work.

V. Summary & Conclusions

In seeking to provide an actor centred constructivist account of the HFC community, the research reported on in this thesis has sought to address a gap at the intersection between science, technology and innovation studies; network governance; UK energy policy literature as they relate to HFC innovation. In particular it drew insights from constructivist policy analysis and network governance literatures to suggest attention be paid not only to the broad systemic and ideational landscapes, but to the relations between networked actors involved in energy innovation governance in practice. Proposing a case study of the HFC community as a means of elaborating on the HFC community while achieving a degree of cross-disciplinary synthesis between these insights; the research embarked upon an interpretivist-constructivist study at the level of the community

itself, centred upon particular points of partnership and collaborative practices. In so doing the research has made a number of significant contributions to our knowledge of the HFC community and literatures on transitions theory, energy and innovation policy.

Firstly the research outlined in this thesis has enabled the elaboration of the first formal description and typology of actors currently present within the UK HFC community. Developed through a synthesis between the data collected, and insights from practice theory (Shove, et al., 2012), constructivist policy analysis (Hall, 2011; Saurugger, 2013), and transitions approaches (Geels, 2002; Schot & Geels, 2008); this typology is not only unique in its substantive focus. It also provides significant insight into the role of contextualised interpretation of interests in explaining how actors at the level of the socio-technical niche or regime come to respond to developments at other levels. Moreover, in identifying the HFC community as comprising actors drawn from organisations which share relatively narrow commercial and techno-scientific competencies and contexts, the thesis raises questions as to the extent it can claim legitimacy for greater policy support for HFC technologies.

In identifying the logic of commercialisation as the primary rationale through which HFCs have been incorporated into the formal institutions for UK energy innovation governance, Chapters 8 and 9 provide an account of how HFCs have been incorporated into the policy process. Moreover in identifying this logic, the thesis has shed additional light on how the emergent mix of market liberalisation, decarbonisation and innovation paradigms (Mitchell, 2008; MacKerron, 2009; Kern, et al., 2014) are being realised in practice in formal institutions, governance networks and the interpretations and strategies of policy actors.

By looking to strategic practices, the research was able to detail the formal and informal institutions through which the HFC community has developed as a policy network; establishing links between research institutes, early-mover and pre-commercial firms at the niche level and policy actors, cautious and enthusiastic incumbents of the existing regimes for energy and transport policy making. In examining the strategic rationales guiding these actors interactions, the researcher was struck by the extent to which, despite their varying interests and strategies, actors displayed high levels of agreement as to what constituted legitimate and appropriate forms of participation in the HFC community. In particular there existed a general agreement that conferences, projects, funding deliberation, evidence production and lobbying were key focal points for the formation of the HFC community as a governance network.

However, the thesis has also noted that pre-existing economic and reputational imbalances between incumbent firms and other actor means that while the former are able to pursue their strategies relatively freely, the latter are often required to adjust their tactics and discourse to accommodate the priorities of their more powerful network partners. This imbalance is to an extent the product of the overarching institutional structures and meta-governance strategies employed by policy actors, grounded in the logic of commercialisation. While actors within the HFC community retain a degree of freedom in the strategies they pursue, it is unclear if any will be capable of challenging incumbent led regimes for HFC innovation, or where such regimes may be headed given their relatively narrow base of support.

Finally while the researcher remains confident these conclusions remain credibly grounded in the context of the HFC community, this is not to say the claims made here will be directly translatable to other policy communities for energy innovation. HFCs are a highly specific technology crossing not

just energy but transport innovation policy making, and the strength of automotive incumbents in shaping its development should not be understated. Moreover, they represent a small sample of the overall range of emergent energy technologies being governed. While it is quite possible that the findings presented here hold true for broader paradigms for energy innovation policy and other technology communities falling under them, researchers looking to transfer the findings of this thesis will need to attend to the specific organisational and institutional contexts involved at these alternative sites or levels of analysis. Furthermore in speaking to the emblematic actors, institutions and strategies of the HFC community, the thesis does not claim to speak to the HFC community in full, or to the specificity of individual cases within it. In practice there exist a number of nuances and differentiations that could not be presented here, rather this account itself reflects a construct designed to make the complexity and heterogeneity of the HFC community communicable to a wider audience. In this respect the author hopes it will be useful, both in helping HFC community actors in clarifying their understandings of their wider networked context, and to the broader community of constructivist, energy innovation and transitions theory scholars.

APPENDIX 1: TEXTS REFERRED TO IN ANALYSIS

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APPENDIX 2: PARTICIPANT RECRUITMENT LETTER

Institute of Applied Social Studies
Muirhead Tower
University of Birmingham
Edgbaston
Birmingham
B15 2TT

[redacted]
[redacted]
[date]

Dear [title] [firstname] [surname],

I am writing to you to request your participation in a research project currently running jointly between the University of Birmingham's Centre for Hydrogen and Fuel Cell Research and Institute of Applied Social Studies. The study is working to examine the role of social practices such as work; language; and relationships in the research and development of a green energy technology. The purpose of the project is to gain an understanding of how a research and development of hydrogen fuel cells is working in practice.

[personal paragraph- why they have they been asked to participate **note:** referees should only be named if they have agreed to be]

Your participation would involve an interview lasting up to two hours at a place and time of your choosing. Following the interview you will be sent a summary of your interview recording should you wish to add clarifications or comments, followed by a summary of preliminary findings which you will also be able to comment upon in writing. Selected participants may also be asked to take part in follow up interviews in 2013, though you will be able to opt out of all further participation following the first interview.

Your participation in this project would be very much appreciated and findings from the study will feed back into the hydrogen fuel cell and technology policy communities with a view to improving communication and practices. Should you wish to participate in the study, or would like to receive more information about the project please feel free to contact me by email or telephone using the details provided above. Alternatively you may wish to contact the Project Supervisor; Dr Stuart Connor by email at [redacted]. I look forward to hearing from you.

Yours faithfully,
Gareth Thomas
Doctoral Researcher
Institute of Applied Social Studies &
Centre for Hydrogen and Fuel Cell Research

APPENDIX 3: ANONYMISED LIST OF INTERVIEW PARTICIPANTS

Case Description	Indicative Participant Job Title *
1. Consultancy Firm to Government and HFC Industry	Partner
2. Early Mover Automotive Manufacturer 1	Chief Executive
3. Early Mover Automotive Manufacturer 2	Chief Executive
4. Energy Utility Incumbent	Head of Micro Generation Technologies
5. Energy Utility Incumbent 2	Manager
6. Government Department	Civil Servant
7. Incumbent Automotive Manufacturer 1	Head of HFCs
8. Incumbent Automotive Manufacturer 2	Manager
9. Incumbent Automotive Manufacturer 3	Government Relations Officer
10. Incumbent Engineering and Chemicals Manufacturer	Analyst and Manager
11. Incumbent Industrial Gas Manufacturer 1	Manager-Hydrogen Energy Team
12. Incumbent Industrial Gas Manufacturer 2	Manager- Hydrogen Energy Team
13. Incumbent Primary Energy Company	Head of HFCs and Public Body Board Member
14. Industry Association	Chief Executive
15. Local Authority 1	Civil Servant
16. Local Authority 1	Civil Servant
17. Local Authority 2	Civil Servant
18. Pre-Commercial HFC Manufacturer 1	Chief Executive
19. Pre-Commercial HFC Manufacturer 2	Chief Executive
20. Pre-Commercial HFC manufacturer 2	Chief Financial Officer
21. Pre-Commercial mCHP Manufacturer	Technology Officer
22. Pre-Commercial mCHP Manufacturer	Chief Operating Officer
23. Public Body 1	Chief Executive
24. Public Body 2	Civil Servant
25. Public Body 3	Civil Servant
26. Public Body (EU)	Civil Servant
27. Research Institute 1	Senior Researcher
28. Research Institute 2	Senior Professor
29. Research Institute 2	Manager
30. Research Institute 2	Professor and Public Body Advisor
31. Research Institute 3	Professor and Public Body Advisor

*Note: Some Job titles have been altered to protect participant anonymity.
Case numbering refers to different organisations/contexts

APPENDIX 4: INTERVIEW SCHEDULE & TOPIC GUIDE

Interview Schedule and Topic Guide

BACKGROUND

Research Goal: To address the role of social actors in the research and development of a green energy technology (hydrogen fuel cells) and increase our understanding of how low carbon transitions policy is working in practise.

Purpose of the interview: As someone whose work has a direct bearing on hydrogen and fuel cell innovation your responses will be valuable in providing a description of the practices your work involves, the views which inform it and the wider community of which your work is part.

Research Questions:

1. Who are the key social, governmental and industrial actors in the field of Hydrogen and other renewable energy promotion?
2. What strategies do actors employ to argue their case for or against Hydrogen energy?
3. How do these actors and strategies affect further research and development of fuel cell technologies?

INTRODUCTION

- Introduce self and exchange pleasantries
- Briefly reiterate the purpose of the study and explain the format of the interview as a flexible 'conversation with a purpose', outline the topics to be covered, types of questions and ask if participant has any queries.
- Ensure the participant is aware they will be contacted afterwards to provide feedback for comments and possibly to request participation in a follow up interview. Assure them they may opt out of this at any time.
- Provide reassurance of confidentiality, but remind participant of possibility they could be identified in interview extracts published under pseudonyms. Reassure them of their right to comment on interview summary prior to publication.
- Remind the participant of their right to withdraw at any time.
- Ask if the participant is willing for the interview to be recorded and gain written informed consent using information sheet and consent form.
- Ensure participant is ready and begin recording.

THE INTERVIEW

Interviews in this study are with a wide variety of individuals from a wide range of professional backgrounds. It is unlikely that identical question wording will be appropriate to each participant, different terminologies may be necessary for questions on the same topic, and clarifications sought in some cases where they are not necessary in others. The following guide is intended to be used flexibly and reflexively in the way most appropriate to the context of the interview and the

participant in question. Below is a list of five key topic areas that will require covering, they may be covered in any order that makes sense in the context of the interview conversation.

Key topics:

- **Narratives of fuel cells or green technology:** Getting the participant to discuss the ‘story lines’ through which they understand fuel cells, the need for them, the opportunities and the constraints on further research, development and adoption. Free narrative is most appropriate here but initial questions might focus on the wider environmental, political and economic climate, public attitudes, the reasons or purpose of the participants own work in the field. Challenges may also be offered by suggesting alternate narratives to those being used by the participant which which they may chose to explore, contest or ignore.
- **Institutional Setting:** The organisation in which the participant works, its purpose, status and culture. Questions may also relate to how decisions are made and actions carried out, and how the organisation works with other organisations both in terms of official and unofficial relationships. Discussion of this topic might begin with questions relating to the participants role in the organisation, ‘what brings you here?’ or the more general ‘how do things work here?’, ‘who does what?’ before shifting to the perceived role of the organisation ‘what does this organisation do?’, ‘how’, ‘why?’. Final questioning on relationships with other organisations might be approached by asking after perceived competitors, partners, suppliers or customers.
- **Relationships:** The participants role as a member of a professional community, the types of people engaged with closely and those with whom contact is more remote. Questions may relate to personal labels or short hand for their own identity in relation to others; engineer, academic, environmentalist, research sponsor etc.
- **Practises:** The day to day work of the participant, what this actually involves in terms of concrete action and the meaning attributed to these actions. Begin with asking about the apparently mundane day to day activities of life in the lab or office, ‘what do you do?’, ‘how do you do it?’. Meaning might be discussed later using ‘why’ questions or in relation to the practices of others e.g. colleagues, competitors etc.

ENDING THE INTERVIEW

- Once the above topics have been covered inform the participant that you have no more questions. Sum up what you understand as the key points in the interview and ask if the participant would like to add or clarify anything you may have missed.
- Offer the participant the opportunity to add anything they feel is important or should have been covered in more detail before shutting down the recording equipment.

- Turn off recording equipment and thank participant for their time, ask if they have any questions.
- Explain the process of participant referral and ask if the participant knows any one who might be prepared to be interviewed. Discuss how this may be arranged.
- Remind participant you will be in touch for the purposes of:
 - Mailing interview summary & summary of findings for comments
 - Participant referral (if relevant), and possibly;
 - Arranging a follow up interviewReiterate that such contacts are optional and the participant will be able to withdraw from them at any time.
- Thank participant again leaving contact details should they have any further thoughts or follow up questions.

APPENDIX 5: PARTICIPANT INFORMATION AND CONSENT FORM:

Information for Participants

Research Goal & Purpose: To address the role of social actors in the research and development of a green energy technology (hydrogen fuel cells).

Purpose of the interview: As someone whose work has a direct bearing on hydrogen and fuel cell innovation your responses will be valuable in providing a description of the practices your work involves, the views which inform it and the wider community of which your work is part.

Nature of participation: The interview will be recorded and follow a semi-structured, conversational format. The interview shall last up to two hours, should you wish to take a break at any time please inform the interviewer who can pause recording. Following the interview you will be sent a summary of your interview recording, and later, a summary of the research findings, accompanied by requests for any comments you may wish to add. You may be contacted again to arrange a follow up interview in 2013, participation in which will be subject to your consent at that time.

Topics Covered: The interview will cover the work of yourself and your organisation, your professional relationships and the meanings you attribute to green energy technologies. After the interview you will also be asked if you know of another relevant person who you recommend we interview, this is optional and you are free to decline for any reason.

Confidentiality: Whilst best efforts will be made to maintain participant confidentiality, interview extracts may appear under pseudonyms in subsequent publications. There is therefore a risk that participants may be identifiable through the content of such extracts. For this reason participants will have the opportunity to comment on or clarify interview summaries, and request access to full transcriptions prior to any material being published. Alternatively you may opt out of being directly quoted in research outputs altogether, to do so, please tick here.....[]

Right to Withdraw: Should you wish to withdraw during the interview for any reason, please inform the interviewer. Following the interview you will have a period of two months during which you may withdraw from the study and have your interview data destroyed, after which time your data shall be used in line with the purposes outlined above. Participants will retain the right to withdraw from all follow up work at any time and can do so by contacting the principal investigator.

Data access and Storage: Interview summaries will be sent to participants by recorded mail within 1 month. Only the researcher and participant will have access to full recordings. Interview data will be stored electronically until the completion of the project and destroyed thereafter. At all times data will be stored under password protection, in line with the provision of the Data Protection Act (1998). You may request access to your data at any time.

Participant Consent

I hereby agree that I give my free and informed consent to participating in the research project and subsequent uses of my interview data for the purposes outlined above. I understand that my information will be stored in accordance with the Data Protection Act (1998), and that all data referring to my participation will be destroyed on completion of the project. I am aware that I am free to withdraw from this project at any time.

Signed (participant):

Time & Date:

APPENDIX 6: EARLY NARRATIVE ANALYSIS FOR POLICY ACTORS

Body	Parent Department & Competence	Context	Meaning	Relevant Activities	Example actions and projects
TSB	BIS Funder of innovation for business growth	Government Innovation Agency operating under the auspices of BIS. The TSB is tasked with funding RD&D activities in areas with global market potential for UK companies.	Energy and Transport are largest among the 18 priority areas the TSB funds on the basis of their global market potential. HFCs projects can fall under both.	Funding competitions for UK businesses looking to develop and demonstrate products, upscale manufacturing and build relationships with potential customers.	Low Carbon Vehicle Innovation Platform
EPSRC	BIS Funder of academic research	Funded via BIS with strategic input from other bodies. Funds academic research and postgraduate training to develop knowledge and skills pertinent to business, government and capable of making an impact to areas of societal concern.	HFCs are funded under 'Energy' as one of EPSRC's seven core thematic funding areas.	Open competition for academic research funding, as well as funding competitions to host pre-designated centres for research and postgraduate training.	SuperGen Network Hub CDT in H&FCs
Carbon Trust	Formerly DECC Business Decarbonisation and Technology Assessment	Not-for-dividend company established but by but independent from DECC. Tasked with accelerating the move to a low-carbon economy through CO ₂ reduction, energy efficiency, and commercialising low-carbon technologies.	HFCs as promising low-carbon technology in need of investment and support.	Provides funding for low-carbon technologies via equity investments, R&D funding competitions and tailored business and partnering advice.	Investment in Ceres Power PEM Fuel Cell Challenge
OLEV	BIS/DECC/ DfT Cross departmental knowledge of low carbon transport	Cross-Whitehall coordination group for low emission vehicles. Staffed by civil servants from BIS, DECC and DTI.	FCEVs as ultra-low emission vehicles	Coordination between government and industry and provision of grants to reduce purchase cost of Low emission vehicles and infrastructure.	UK H ₂ Mobility Project Low Carbon Car Grant

	infrastructure, regulation and technologies				
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APPENDIX 7: UKHM MEMBERSHIP AND RESEARCH PARTICIPANTS

The membership of UKHM has been somewhat fluid, and has expanded since field work for the study concluded. Table 1 contains those organisations participating during the period to which this thesis refers, with Table 2 containing new entrants that have publicly announced their participation since April 2013. Table 3 contains a list of organisations credited as participating in UKHMs market research process.

Table 1: UKH2 Mobility Participating Organisations to April 2013

Participant Organisation	Nature of Business	Participation
Daimler AG	Incumbent Automotive	Phases 1,2 & 3
Hyundai Motor Company	Incumbent Automotive	Phases 1,2 & 3
Nissan Motor Manufacturing (UK) Limited	Incumbent Automotive	Phases 1,2 & 3
Tata Motors European Technical Centre plc	Incumbent Automotive	Phase 1
Toyota Motor Corporation	Incumbent Automotive	Phases 1,2 & 3
Vauxhall Motors	Incumbent Automotive	Phase 1
Johnson Matthey PLC	Incumbent Chemicals & Engineering	Phases 1,2 & 3
Intelligent Energy Limited	Pre-commercial HFC	Phases 1,2 & 3
ITM Power PLC	Pre-commercial HFC	Phases 1,2 & 3
Air Liquide Hydrogen Energy, SA	Incumbent Industrial Gas	Phases 1,2 & 3
Air Products PLC	Incumbent Industrial Gas	Phase 1
The BOC Group Limited	Incumbent Industrial Gas	Phases 1,2 & 3
Scottish and Southern Energy plc	Energy Utility	Phases 1,2 & 3
Department for Business, Innovation & Skills	Government Department	Phases 1,2 & 3
Department of Energy and Climate Change	Government Department	Phases 1,2 & 3
Department for Transport	Government Department	Phases 1,2 & 3
Fuel Cells and Hydrogen Joint Undertaking	Governance Institution (EU)	Phases 1,2 & 3
Morrisons	Supermarket & Fuel Retailer	Phases 2 & 3

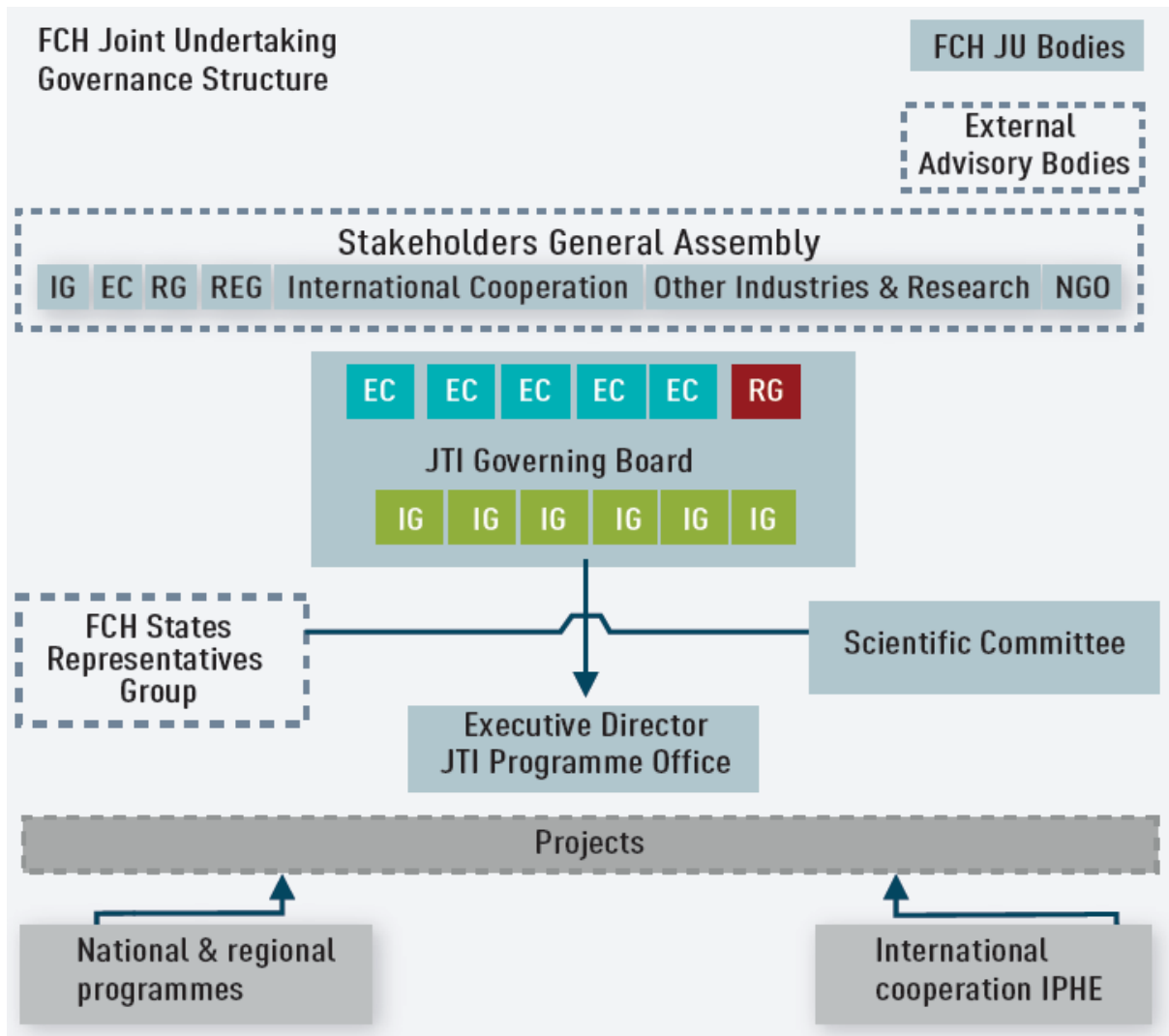
Table 2: UKH2 Mobility Participating Organisations post April 2013

Participating Organisation	Industry Sector	Participation
Sainsbury's	Supermarket & Fuel Retailer	Phases 2 & 3
Transport Scotland	Governance Institution	Phase 3
Welsh Government	Governance Institution	Phase 3
Greater London Authority	Local Authority	Phase 3

Table 3: UKHM Research Participants

Company	Nature Of Business
Arval	Incumbent Car Hire
BVRLA	Incumbent Vehicle rental and leasing association
CAP	Incumbent Risk management and valuations for auto industry
Commercial Group	Incumbent Business Services
DHL	Incumbent Logistics
Lex Autolease	Incumbent Car Hire and Vehicle Leasing
National Grid	Incumbent Grid Regulator
Sainsbury's	Incumbent Supermarket & Fuel Retailer
Shell	Incumbent Fuel Retailer
UPS	Incumbent Logistics

APPENDIX 8: FCHJU GOVERNANCE STRUCTURE



Source: FCHJU, 2014, p.46

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