PhD-FLSHASE-2015-05
The Faculty of Language and Literature, Humanities, Arts and Education

# DISSERTATION

Defense held on 25/02/2015 in Luxembourg

to obtain the degree of

## DOCTEUR DE L'UNIVERSITÉ DU LUXEMBOURG

## EN *SCIENCE POLITIQUES*

by


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# EUROPEAN UNION RESEARCH AND INNOVATION POLICY: THE CO-PRODUCTION OF POLICY AND EXPERTISE IN THE CASE OF HYDROGEN AND FUEL CELL TECHNOLOGIES

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# Acknowledgements

I would like express my gratitude to everyone who supported me during the work on this thesis. In particular, I would like to thank my supervisors Ariane König and Robert Harmsen for guiding me through the accomplishment of my dissertation. Without their encouragement and valuable comments I would never have been able to complete my dissertation. I am incredibly grateful for all of the support that I received during the last four years.

I would also like to thank all the other persons who supported me in one way or another during the conduct of this thesis. I decided not to list their names for avoiding the risk of forgetting to mention someone but I am sure that those who are meant will know. In addition, I would like to thank all of my interviewees who have patiently answered my questions and supported the completion of this dissertation.

Last but not least, I would like to acknowledge the support of the “Fonds National de la Recherche" in Luxembourg, funding this research from March 2011 to February 2015 within the AFR-PhD grant scheme (Project Reference 1072733). Without the generous financial support of the “Fonds National de la Recherche" the thesis at hand would never have come into being.

## Abstract

This doctoral thesis investigates the governance of European Union research and innovation policy through a case study of the co-production of European Union hydrogen and fuel cell policy and expertise from 2000-2014. In so doing, it contributes to filling a research gap as the scholarly literature has only paid little attention to European Union research and innovation policy so far. The few studies that exist remain mostly on the theoretical level and focus predominantly on the role of the interests of the actors involved while neglecting the role of scientific information and technological progress. To address these shortcomings this thesis draws on insights from the Science and Technology Studies and the Public Policy literature in order to put forward an innovative theoretical framework centred on the co-production of policy and expertise, assuming that both are produced together and in relation to each other.

The empirical results highlight above all two issues in the co-production of policy and expertise in the promotion of hydrogen and fuel cell technologies by the European Commission. First, the bureaucratic logic of the policy process has trumped the scientific logic of the provision of expertise by defining the role of expertise in the policy process. While setting hydrogen and fuel cells on the political agenda required the promising vision of a future hydrogen economy to raise attention for these technologies, the decision to launch a public-private partnership had to be legitimized by concrete political and technical objectives that were to be achieved by the development of hydrogen and fuel cells. Second, many officials of the European Commission understood innovation primarily as the development of new commercial products. This led to a commercialization of the scientific process which enabled large private enterprises to play the key role in the development of hydrogen and fuel cell technologies in the European Union at the expense of public research institutes and universities. Hence the development of hydrogen and fuel cells focused rather on improving and validating already existing, well-known technologies towards market entry than on reaching a fundamental understanding of new, less-known technologies.

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# Part I

# Introduction

# 1 The motivation of the study

This thesis presents an exploratory case study of the co-production of European Union hydrogen and fuel cell policy and expertise in the years of 2000-2014. In so doing, it contributes to filling a research gap in the rarely explored policy field of European Union research and innovation policy after the turn of the millennium. For this purpose, an innovative theoretical framework is put forward by drawing on the two disciplinary fields of Public Policy and Science and Technology Studies which have so far only taken little notice of each other. This theoretical framework provides the foundation for the analysis of the promotion of hydrogen and fuel cells by the European Commission in the years of 2000-2014. Indeed, the promotion of these alternative energy technologies reflects the general trends of a renewed European Union research and innovation policy that was to contribute to the development of the European knowledge society.

In fact, the first decade of the new millennium was earmarked for the development of the European knowledge society by the European Union (hereinafter EU). The European Council declared the transformation of the EU into the "most competitive and dynamic knowledge-based economy in the world" to be the top priority for the new decade at its summit in Lisbon in March 2000 (European Council 2000). This so-called Lisbon Agenda embodied a new political momentum for research and innovation which were perceived as the remedy for economic stagnation and high unemployment. Consequently, the establishment of a European area of research and innovation was promoted as one of the key means to bring about the desired knowledge society (European Council 2000).

However, there are many different conceptions of innovation and there are only very few studies that have actually looked at how the new EU research and innovation (hereinafter R&I) policy was implemented in detail. Hence one might wonder how the EC's new focus on research and innovation was translated into practice. What concrete understanding of innovation did the EC pursue and how did it conceive of the relations between economic growth, innovation, research, science, and technology? Furthermore, one might wonder whether the new EU R&I policy brought about actual changes in the conduct of research and innovation in the EU or whether the new focus on research and innovation primarily remained a change at the rhetorical level.

In order to provide answers to these questions, and to highlight the actual nature of the new EU R&I policy, this thesis presents an exploratory case study of the promotion of hydrogen and fuel cell technologies by the EC. In fact, the promotion of hydrogen and fuel cell technologies by the EC in the years of 2000-2014 constitutes a prime example of the new EU R&I policy that was to bring about the European knowledge society. These alternative energy technologies were placed on the European innovation agenda in the first years of the new millennium and subsequently promoted through novel policy instruments that were to implement the new EU R&I policy. Therefore, an investigation of EU hydrogen and fuel cell policy in the years of 2000-2014 can contribute insights on the actual nature of the new EU R&I policy after the Lisbon Council in March 2000.

For this purpose, this thesis puts forward an innovative theoretical framework drawing on insights from the Science and Technology Studies and the Discourse Coalitions approach from the Public Policy literature. While these two disciplinary fields have only taken little notice of each other so far, this thesis demonstrates that drawing on the Science and Technology Studies and the Public Policy literature in a complementary manner provides a useful tool to highlight the new understanding of innovation of the EC and its new conception of the relations between economic growth, innovation, research, science, and technology. In addition to this theoretical innovation, this thesis constitutes one of the few empirical studies of the new EU R&I policy launched after the Lisbon Council contributing to a deeper understanding of this rather rarely explored policy field.

This introductory chapter is to explain the motivation of this study in more detail and to provide an outlook on the subsequent chapters. First, the new focus of the EU on research and innovation and the development of the new EU R&I policy after the Lisbon Council is described. Second, it is illustrated that the empirical case of the promotion of hydrogen and fuel cell technologies constitutes a prime example of the new EU R&I policy. Third, it is explained how this empirical case of to be analysed through the innovative theoretical framework developed by drawing on the Science and Technology Studies and the Public Policy literature. Finally, an outlook on the further proceeding of this thesis is provided explaining how each individual chapter contributes to the overall objective of highlighting the promotion of hydrogen and fuel cell technologies by the EC.

## 1.1 The innovation turn in European research policy

EU research policy has been evolving constantly from the 1960s up to the present day. While the 1960s and the 1970s primarily saw the launch of individual European research organizations, the development of a European research policy gained momentum in the 1980s with the launch of the first Research Framework Programme of the EC (Jansen and Semmet 2012, 17). The budget and also the importance of the Framework Programmes have seen a steady rise from the 1980s to the launch of the eighth Framework Programme in 2014 so that the Framework Programmes became the main building block of EU research policy over time. This evolution of EU research policy from the 1960s up to the present day was always shaped by shifting understandings of the relation between research, science, and technology development.

The Lisbon Council in March 2000 for instance constitutes a milestone in the development of EU research and innovation policy. In fact, the notion of a research and innovation policy did not exist 1970s and 1980s, but rather the EU spoke of pursuing a research and development policy or research and technological development policy. Therefore, this shift in the official rhetorics of the EU that gained ground in the late 1990s was often labelled as the “innovation turn” (Sanz-Menendez and Borrás 2000, 1, 2). At the heart of the innovation turn lay a new understanding of the relation between research, innovation, science, technology, and economic development. In fact, research, innovation, and science were perceived as the key factors for economic growth and competitiveness.

This new understanding of research, innovation, and science as being the key drivers of economic growth and competitiveness resulted in an increased political momentum for the development of a new EU R&I policy. European policy-makers seized this opportunity and launched several new policy instruments and institutions in order to implement the European area of research and innovation which was to contribute to the transformation of the EU into the “most competitive and dynamic knowledge-based economy in the world” (European Council 2000). The EC launched the first twenty Technology Platforms in 2004 (European Commission 2005c, 8) and the first five Joint Technology Platforms in 2008 (European Commission 2007c, 4, 2012a; JTI Sherpas’ Group 2010, 27–31). Both Technology Platforms and Joint Technology Initiatives constitute novel policy instruments of the new EU R&I policy that were to implement the EC’s new understanding of innovation. In addition, the EU launched new organizations that were to pursue research and innovation in new ways such as the European Research Council in 2007 and the European Institute of Innovation and Technology in 2008 (Jansen and Semmet 2012, 20).

However, there are only few studies on the new EU R&I policy and little is known about what the innovation turn brought about in practice. What changes did for instance the new policy instruments of Technology Platforms and Joint Technology Initiatives bring about in the actual scientific process? How did the EC’s new understanding of the relation between research, innovation, science, technology, and economic growth impact the actual development of new technologies? This thesis sheds light on what results the innovation turn has brought about in practice through an empirical case study of the promotion of hydrogen and fuel cell technologies by the EC which constitutes a prime example of the new EU R&I policy, as will be explained in more detail in the following subchapter.

## 1.2 Hydrogen and fuel cell technologies in the innovation turn in European research policy

The development of renewable energy sources and alternative energy technologies has gained momentum in the past decades (Christiansen 2002, 242). Some of the main drivers of this development are the debates on climate change (Bahn, Edwards, Knutti, and Stocker 2011, 334, 335; Intergovernmental Panel on Climate Change 2007, 30–39, 45–54; MacKay 2008, 5–18), rising oil prices (Schindler and Held 2009, 60), and the scarcity of crude oil (International Energy Agency 2010, 6). In a nutshell, many expect oil to get scarce and expensive in the future and many believe that the Greenhouse Gas emissions resulting from the combustion of fossil fuels are the main driver behind climate change. Consequently, the reliance of present-day energy systems on fossil energy sources is increasingly perceived as problematic. This benefits the development of renewable energy sources and alternative energy technologies as these provide the opportunity for establishing a full energy cycle from generation to consumption without the release of Greenhouse Gas emissions into the atmosphere. Hence renewable energy sources and alternative energy technologies are discussed as potential solutions for a more sustainable development as they would allow for the decoupling of economic growth from the combustion of fossil energies and the resulting Greenhouse Gas (hereinafter GHG) emissions.

Hydrogen and fuel cells constitute one of the alternative energy technologies that open up the chance to deploy renewable energy sources in GHG-free energy cycles in transportation and electricity and heat generation. Indeed, the following quotations indicate that hydrogen and fuel cells were placed on the EU innovation agenda in the first years of the new millennium against the background of the debates on climate change and the shift from fossil to renewable energy sources. Romano Prodi, the then President of the EC, announced in 2002: “Hydrogen technology will not only reduce our energy dependency and GHG emissions; in the long run it will also change considerably our socio-economic model and create new opportunities for developing countries” (European Commission 2002d, 1). Loyola de Palacio, the then Commissioner for Energy, said: “Hydrogen brings important opportunities for the distribution of sustainable energy (e.g. renewables) and for decentralised power generation” (European Commission 2002d, 1). In addition, Philippe

Busquin the then Commissioner for Research, stated: “To meet the stringent Kyoto Protocol targets, the EU will increase the use of renewable energy sources and substitute fuels – including hydrogen” (European Commission 2002d, 1).

In fact, the promotion of hydrogen and fuel cell technologies constitutes a prime example of the innovation turn in EU research policy. While the development of these technologies has been funded under different schemes of the Framework Programmes of the EC since 1986 (European Commission 2006e, 9), the EU did not pursue a specific hydrogen and fuel cell policy until these technologies became part of its new innovation agenda in the first years of the new millennium. After Romano Prodi, Loyola de Palacio, and Philippe Busquin made hydrogen and fuel cells part of the new innovation agenda in 2002, the EC began to promote these technologies through the novel policy instruments of its new EU R&I policy. In January 2004 the European Hydrogen and Fuel Cell Technology Platform was launched (European Commission 2004a) and in 2008 the Council of the European Union launched a Joint Technology Initiative for the development hydrogen and fuel cell technologies (Council of the European Union 2008, 1, 4).

These illustrations pointed out two salient aspects of the empirical case that is investigated in this thesis. First, the top of the EC perceived hydrogen and fuel cells as key technologies of the future that were to contribute to sustainable development and to fighting climate change. Second, the promotion of hydrogen and fuel cells exemplifies the innovation turn in EU research policy as the application of the novel policy instruments of the new EU R&I policy for the development of these technologies demonstrates. Against this background, this thesis provides an empirical case study of the promotion of hydrogen and fuel cells by the EC in the years of 2000-2014 in order to draw general conclusions on the new European research and innovation policy.

For this purpose, several questions on the promotion of hydrogen and fuel cells by the EC have to be addressed such as: How were hydrogen and fuel cell technologies set on the European agenda? How was it decided to launch a Joint Technology Initiative for these technologies? How was this Joint Technology Initiative implemented? Through answering these questions this thesis will shed light on how the new European research and innovation policy was implemented in practice and what changes it brought about in comparison to the European research policy before the innovation turn. In order to do so, this thesis puts forward an innovative theoretical framework by drawing upon the scholarly literature of the two disciplinary fields of Public Policy and Science and Technology Studies as will be illustrated in the following subchapter.

## 1.3 A co-productionist perspective on the promotion of hydrogen and fuel cell technologies

The new understanding of the relation between research, innovation, science, technology, and economic development that lay behind the innovation turn in EU research policy was, among others, the result of the specific expertise that was provided to European policy-makers. In fact, the political focus on innovation in the first years of the new millennium reflects an intensified scientific debate in the 1980s and 1990s on the role of science and technology development in the process of innovation. Scientific models such as the system of innovation approach and the Triple Helix concept stressed that innovation results from a complex set of relationships between different actors such as governments, enterprises, and research institutions (Etzkowitz and Leydesdorff 2000; Malerba 2004). The new EU research and innovation policy and the idea of a European knowledge society relied on this expertise and its portrayal of science and technology.

Hence there are complex articulations between policy and expertise which relate to each other in many different ways. Policy-makers for instance rely on expertise that outlines how science, technology, and economic development relate to each other in order to formulate the policies to achieve their political objectives. Simultaneously, scientists and experts are constantly developing new expertise based on the experiences from ongoing research and innovation programmes and against the background of current political discussions. These examples are, of course, only a tiny piece in the intricate puzzle of the relation between policy and expertise. The main point is, however, that policy and expertise are two interrelated phenomena characterized by complex articulations between each other.

Against this background, this thesis suggests adopting a co-productionist perspective on policy and expertise in order to investigate the new EU R&I policy and its underlying understanding of the relation between research, innovation, science, technology, and economic development on the empirical case of the promotion of hydrogen and fuel cell technologies. For this purpose, this thesis draws upon the two disciplinary fields of Public Policy and Science and Technology Studies and puts forward an innovative theoretical framework for the analysis of the co-production of policy and expertise in the case of hydrogen and fuel cell technologies. In fact, these two disciplinary fields have only taken little notice of each other so far. However, this thesis demonstrates that combining important insights from both strands of literature provides an additional value for the analysis of the promotion of hydrogen and fuel cells by the EC.

While the wider Public Policy literature is considered in order to account for the development of EU hydrogen and fuel policy, the insights of the Science and Technology Studies are applied to shed light on the provision of expertise on these technologies. In this way several questions that highlight the complex articulations between policy and expertise in the case of hydrogen and fuel cell technologies will be addressed such as: How did the EC conceive of hydrogen and fuel cell technologies and what actors provided the expertise that led to this understanding? How did the expertise outlining the importance of hydrogen and fuel cells for the achievement of EU policy objectives change over time? How did the research and innovation programmes launched for hydrogen and fuel cells and the overall political discussions at that time affect the development of this expertise?

These questions need to be answered in order to shed light on the parallel and interrelated production of policy and expertise in the promotion of hydrogen and fuel cell technologies by the EC in the years of 2000-2014. In fact, all of them can be summed up into the central research question of this thesis:

How are European hydrogen and fuel cell policy and expertise co-produced?

## 1.4 Thesis outline

This thesis encompasses four parts covering ten chapters, all of which contribute a specific part to the analysis of the co-production of EU hydrogen and fuel cell policy and expertise. The first part, consisting of this chapter, constitutes the introduction highlighting the motivation of this study and providing an outlook on the further parts and chapters of this thesis. The second part, encompassing the chapters 2-5, outlines the theoretical background of this thesis as well as the empirical case investigated and the methodology applied. Subsequently, part three presents the bulk of this thesis by illustrating the results of the empirical analysis of the co-production of EU hydrogen and fuel cell policy and expertise in the chapters 6-9. Part four summarizes the empirical results of the co-production of EU hydrogen and fuel cell policy and expertise and elaborates the broader, theoretical conclusions that can be drawn from this case study on the governance of the EU research and innovation policy in general in chapter 10. Finally, the reader will find the references and the annex at the end of this thesis.

In the following paragraphs, the focus of the individual chapters in the different parts is described in more detail in order to illustrate to the reader the specific part that each chapter contributes to the overall aim of shedding light on the co-production of EU hydrogen and fuel cell policy and expertise.

*Part II: Theoretical background, case description, and methodology*

Following the outline of the practical relevance of an investigation of the co-production of EU hydrogen and fuel cell policy and expertise in this chapter, the second part starts with highlighting the scientific relevance of this thesis in chapter 2 by outlining the gap in research that this thesis attempts to fill. For this purpose, a review of the scholarly literature on the governance of EU research and innovation policy focusing on the Public Policy literature and on the field of Science and Technology Studies is provided. It is pointed out that the existing scholarly literature has largely neglected the role of expertise and that there are almost no empirical studies on the implementation of EU research and innovation policy.

Chapter 3 explains how this thesis is to contribute to filling this gap in research through an innovative theoretical approach which integrates the most important insights from the two research strands of Public Policy and Science and Technology Studies into a coherent framework for the analysis of the co-production of policy and expertise in the promotion of hydrogen and fuel cell technologies by the EC. It is outlined that the role of expertise in policy-making is only treated implicitly in many meso-level public policy approaches. Therefore, it is elaborated how the provision of expertise is analyzed in the field of Science and Technology Studies in order to develop a theoretical framework for the analysis of the co-production of EU hydrogen and fuel cell policy and expertise by drawing on the insights of both the Public Policy literature and Science and Technology Studies.

Chapter 4 provides an in-depth description of the empirical case that is to be analysed by the theoretical framework of this thesis. For this purpose, not only the technical features and the historical development of hydrogen and fuel cells are explained but it is also elaborated in how far the promotion of hydrogen and fuel cell technologies by the EC exemplifies the innovation turn in EU research policy after the Lisbon Council in March 2000. In so doing, it is pointed out in how far the empirical results of this case study of the promotion of hydrogen and fuel cell technologies by the EC allow for drawing general conclusions on the new EU R&I policy.

Chapter 5 explains how the empirical case of the promotion of hydrogen and fuel cell technologies by the EC was approached in practice. For this purpose, the methodology applied in this thesis and the data collected for the empirical analysis are illustrated. The general approach of an exploratory case study design is further explained and an overview of the data sample is provided.

*Part III: Empirical Analysis*

The third part presents the empirical results of this exploratory case study of the co-production of EU hydrogen and fuel cell policy and expertise in the years of 2000-2014. For heuristic purposes, these empirical results have been categorized chronologically into four different stages in EU hydrogen and fuel cell policy and expertise that will be presented consecutively in the four empirical chapters.

Chapter 6 explains how hydrogen and fuel cell technologies have been set on the EU political agenda in the years of 2000-2004. The main outcomes of this first stage in EU hydrogen and fuel cell policy and expertise were the development of the vision of the hydrogen economy and the launch of the Hydrogen and Fuel Cell Technology Platform in 2004.

Chapter 7 highlights the implementation of the Hydrogen and Fuel Cell Technology Platform in the years of 2004-2008 and the launch of a Joint Technology Initiative for hydrogen and fuel cell technologies in 2008. Among others, it is explained how the actors involved in the Hydrogen and Fuel Cell Technology Platform defined a concrete development programme for hydrogen and fuel cells and how the launch of a Joint Technology Initiative for the implementation of this programme was legitimized in an Impact Assessment of the EC.

Chapter 8 explains the implementation and the evaluation of the Joint Technology Initiative for hydrogen and fuel cells that took place in the years of 2007-2011. In so doing, all the issues relating to the implementation of this new policy instrument are highlighted, ranging from the negotiation of a governance structure to the practical problems encountered. In addition, it is outlined how the first interim evaluation of the Joint Technology

Initiative for hydrogen and fuel cells was conducted by external experts who were appointed by the EC.

The last empirical chapter (9) explains the developments that have led to the continuation of the Joint Technology Initiative for hydrogen and fuel cells in the eighth Framework Programme of the EC in the years of 2011-2014. Based on a proposal of the EC, the Council of the EU legally established the continuation of the Joint Technology Initiative for hydrogen and fuel cells on $6^{th}$ May 2014 for the period of time until 31 December 2024 (Council of the European Union 2014).

*Part IV: Conclusions*

The fourth part consisting of chapter 10 illustrates the main conclusions of this thesis. For this purpose, a summary of the empirical results is provided and it is elaborated what wider conclusions can be drawn from this case study of the co-production of EU hydrogen and fuel cell policy and expertise on the governance of new EU R&I policy in general. Furthermore, it is outlined how the findings of this thesis contribute to the scholarly literature on EU R&I policy. Above all, it is pointed out how the findings of this thesis supplement and confirm the results of other studies and how highlighting the governance of EU R&I policy from this innovative theoretical framework enriches the existing scholarly literature. In addition, some opportunities for further research that could build on the insights gained from this investigation of the co-production of EU hydrogen and fuel cell policy and expertise are indicated.

# Part II

# Theoretical background, case description, and methodology

# 2 The governance of European research and innovation policy

This chapter illustrates the scientific relevance of a study of the co-production of European hydrogen and fuel cell (hereinafter H & FC) policy and expertise. For this reason, it provides a review of the scholarly literature on the governance of European Union research and innovation policy (hereinafter EU R&I policy) and outlines the gap in research that this thesis attempts to fill. More specifically, it is shown that the role of expertise in the governance of EU R&I policy has been largely neglected so far and that there is a lack of empirical studies on the implementation and evaluation of EU R&I policy. This thesis contributes to filling this gap in research through an analysis of the co-production of EU H & FC policy and expertise. For this purpose, the scholarly literature on the provision of expertise will be elaborated in chapter 3 that presents an innovative theoretical framework for the analysis of the co-production of EU H & FC policy and expertise. Subsequently, chapter 4 describes the empirical case of the promotion of hydrogen and fuel cell technologies in the EU that is investigated in this thesis. First, however, this chapter outlines the literature review on the governance of EU R&I policy and provides a general overview of EU R&I policy.

As many other technologies, hydrogen and fuel cells are promoted through the Framework Programmes of the EU. Therefore, the governance of EU R&I policy constitutes the wider context of this study. Consequently, the historical development of European research and innovation policy will be outlined in the first part of this chapter. Thereafter, subchapter 2.2 provides a summary of the scholarly literature on the governance of European research and innovation policy and outlines the gap in research identified. Subsequently, the main insights of this chapter will be summarized in subchapter 2.3 and it will be illustrated how a study of the co-production of EU H & FC policy and expertise could contribute to filling the gap in research on the governance of EU R&I policy.

## 2.1 An overview of European research and innovation policy

Alternative energy technologies such as H & FC are, among others, promoted by European research and innovation policy. In fact, energy technologies have constituted a key factor in EU R&I policy right from the outset. However, before an overview of the past and present EU R&I policy is provided, this subchapter first starts with some contemplations on the notion of innovation. These are to clarify why EU R&I policy can be described as being at the interface of several other policy fields such as research and development policy, science and technology policy, industrial policy and energy policy. This ambiguity of R&I policy stems primarily from the fuzzy notion of innovation that is defined, understood, and applied very differently in diverse contexts.

*The conceptualization of innovation*

First of all, when speaking of innovation, it is inevitable to further clarify what is actually meant with this notion. Traditionally, people have thought of innovation as economically successful inventions that is to say an invention becomes an innovation when it succeeds as a product on the market and reaches broad societal utilization. While this understanding of innovation is still widespread, it has been supplemented by for instance the notion of social innovation that is often used to denote organizational changes in the public sector (e.g. Howaldt and Schwarz 2010). Furthermore, it should be noted that technologies are not always developed to be launched on the market and to be available to the broader public. Manned airspace or the atomic bomb provide good examples of technologies that are regarded as successful innovations although they have not been developed for broader public usage but rather for military and scientific reasons.

These examples point to the notions of research and technology development which are not less complicated than innovation and which complicate the notion of innovation even more as their relation is contested. A common and yet controversial distinction is for instance the one between basic and applied research. Basic research is often defined as research that aims at exploring entirely novel mechanisms while applied research is understood as the further improvement of already well-known technologies. This way of thinking is widely known as the linear model of innovation and traditionally attributed to Vinevar Bush. Its underlying assumption is a linear development of innovation from basic research over applied research to development, production and finally diffusion (Godin 2006, 639).

More recent Science and Technology Studies approaches that aim at the explanation of innovation often apply the linear model of innovation as point of departure in order to outline their own understanding of innovation in contrast to the linear one. Donald E. Stokes for instance criticizes the linear distinction between basic and applied research and argues that basic research can aim at both the fundamental understanding of a new technology and its further improvement for usage (Stokes 1997, 72–75). Etzkowitz & Leyesdorff have developed the Triple Helix Model that conceives of innovation as the result of a co-evolutionary process of transformations within the three spheres of academia, industry, and the state which finally leads to stabilized trajectories (Etzkowitz and Leydesdorff 2000, 113, 114). Building on the approach put forward by Etzkowitz & Leyesdorff (2000), several scholars have suggested to add a fourth sphere in the form of civil society or the broader public and to extend the Triple Helix Model to the Quadruple Helix Model (Carayannis and Campbell 2011; Leydesdorff 2012).

Several other STS approaches that aim at explaining innovation can be grouped under the two headings of innovation systems and transition studies (often also referred to as multi-level perspective). Recently, various scholars have compared and attempted to synthesize these two sides (see for example Geels 2004; Genus and Coles 2008; Weber and Rohracher 2012). In general, one can say that innovation system approaches put a focus on micro-level interactions, while transition studies mainly look at long-term transformations from micro- to macro-level (Weber and Rohracher 2012, 1039).[1]

Thus the main feature of transition studies is to distinguish between a niche, a regime and a landscape level that all relate to each other in a nested character which means that the actions of actors in niches are affected by the situation on the regime- and on the landscape-level (Geels 2002, 1261). Niches are ascribed a key role in the development of radical innovations as they constitute protected areas that allow experimenting and improving novel and at the beginning often expensive and cumbersome technologies (Geels 2002, 1261). Regimes consist of rules and institutions that provide guidance for the actions of diverse societal groups, while landscapes contain factors such as oil prices, economic growth, broad political coalitions, environmental problems, wars, emigration and cultural and normative values that constrain and enable the actions of the actors in the configuration (Geels 2002, 1260). Hence transition studies emphasize the importance of the specific conditions at each level that can hamper and trigger the development of certain innovations.

There are at least four main system of innovation approaches that, among others, differ with respect to the (geographical) level of the analysis: regional, national, sectoral and technological. As their name suggests, regional and national system of innovation approaches focus on the level of regions or nation states and thus also on the specific institutions that characterize these such as local and regional authorities or national governments. Sectoral systems of innovation focus on “a set of agents carrying out market and non-market interactions for the creation, production and sale of sectoral products” (Malerba 2004, 10). A sector is defined as “a set of activities that are unified by some related product group for a given or emerging demand and that share some basic knowledge” (Malerba 2004, 9, 10). In contrast, a technological system of innovation is defined as “a network of agents interacting in the economic/industrial area under a particular institutional

1 It should be noted that there are exceptions such as the approach of Strategic Niche Management as introduced by Kemp et al. (Kemp, Schot, and Hoogma 1998). Strategic Niche Management looks explicitly at the micro-level and aims at supporting policy-makers in creating niches that are to boost the development of the technology desired.

infrastructure and involved in the generation, diffusion, and utilization of technology" (Carlsson and Stankiewicz 1991, 94).[2]

These brief illustrations should clarify that there are diverse understandings of innovation and the processes that lead to a broad societal utilization of new technologies. This, of course, has implications for European policy-makers. They have to define how they conceive of innovation in order to be able to support this process.

### *The road towards a European innovation policy*

As outlined above, the notion of innovation is strongly related to the notion of research, science and technology development. Thus it may not come as a surprise that EU innovation policy, in fact, emerged from EU research and development policy. Sanz-Menendez & Borrás call this the "innovation turn" and argue that EU research and technological development policy has been transformed into the broader concept of innovation policy in the 90s (Sanz-Menendez and Borrás 2000, 1, 2). The following paragraphs will first provide a brief description of the historical development towards EU innovation policy before a closer look is taken at the understanding of innovation since the Lisbon Council in 2000.

The beginning of EU research and innovation policy can be traced back to the 50s and has, since then, developed along the two distinct pathways of European research institutions und intergovernmental research organizations. Both fund and organize research and technology development at a European level. Yet, while European institutions are governed by European authorities and distribute their budget across borders and irrespective of its allocation, intergovernmental research organizations are dominated by the Member States and national institutions who distribute their budget according to the principle of juste retour that is to say Member States expect that their financial contribution is used to fund the participation of their own national research institutes.

2 For a more thorough comparison of the diverse system of innovation approaches and their methodologies see for example Carlsson et al. (Carlsson, Jacobsson, Holmen, and Rickne 2002).

The development of EU R&I policy has ever since been affected by the broader European context. The 50s have seen a focus on securing peace and energy supply with the signature of the treaties on the European Coal and Steel Community in 1951 and EURATOM and the European Economic Community in 1957. Accordingly, the first intergovernmental organization CERN (**C**onseil **E**uropéen pour la **R**echerche **N**ucléaire) has been launched in 1953 and dedicated to high-energy physics research. In 1959 the first European research institution, the Joint Research Center, has been launched as an in-house science service of the European Commission with the task to conduct nuclear R&D and to provide advice for the implementation of EURATOM.

In 1965 the Merger Treaty was signed leading to the fusion of the three communities with the aim of pooling resources. Correspondingly, large-scale intergovernmental research organizations have been launched in key areas such as the European Space Research (ESRO) Organization, the European Space Vehicle Launcher Development Organization (ELDO) and the European Organization for Astronomical Research in the Southern Hemisphere (ESO) in 1962 and the European Molecular Biology Organization in 1964.

This idea of Megascience that is to say the belief that the EU needs large-scale intergovernmental research organizations to become internationally competitive remained a strong influence in the 70s. On the intergovernmental side, the European Space Agency has been created by merging the ESRO, the ELDO and the ESO in 1975 and the European Science Foundation has been launched in 1975 by major national funding agencies. However, the 70s have also seen some progress in the creation of European research institutions. The Directorate-General Research has been established in 1973 and minor European research programmes in energy, health and the environment have been launched in 1974. Yet, these were equipped with a rather negligible budget compared to national funding opportunities.

In the 80s the Member States were more prone to cooperation in research as long as it concerned pre-competitive R&D. In 1983 and 1984 ESPRIT (European Strategic Programme for Research and Development in Information Technology) and the first Framework

Programme were launched. Later on in 1986 the Single European Act brought along the legal manifestation of European R&D and the Framework Programme. However, also EUREKA (European Research Cooperation Agency) was created in 1983 as an intergovernmental counterpart to ESPRIT in order to foster market-oriented R&D. EUREKA was set up completely outside of the EU institutions and has its own secretariat and works strictly bottom-up. Enterprises and scientific institutions search for international partners and apply at their national EUREKA coordinators for funding that is to say each country only funds its own participating institution and in this way haggling around the principle of juste retour was evaded at the price of perfectly implemented juste retour.

The 90s saw a further legal manifestation of European R&D with the introduction of rules and procedures for the legislation of the Framework Programmes in the treaties of Maastricht in 1992 and Amsterdam in 1997. In addition, there was a constant growth in the scope and budget of the FPs. While the first FP had a budget of € 3, 75 billion for the years of 1984 – 1988, the fifth FP was equipped with € 14, 9 billion for the period of 1998 – 2002. Yet, the European Council rejected a proposal of the Commission which aimed at establishing a more industrial and technology oriented R&D policy and hence at abandoning the principle of precompetitive R&D at EU level. Rather, the Council wanted EUREKA to remain the only platform that allows more market-oriented R&D.

*Innovation since Lisbon*

The Lisbon Council in 2000 constitutes the key milestone in the development of a European innovation policy as it has lifted the whole issue of R&D on a completely new level. The new focus on innovation both enabled and required a redefinition of the relation of R&D to other societal areas: “The ideas and arguments about the role of science and technology in economy and society and the dominant RTD policy frames have changed significantly. The boundaries of the policy and considerations about the way in which innovation and technology relate to competitiveness, job-creation, economic growth and social progress have also changed" (Sanz-Menendez and Borrás 2000, 1). In particular, the link to competitiveness has helped EU R&D to gain momentum as it was argued that "industrial competitiveness could be driven by environmentally friendly innovation and enhanced social provision, in addition to intensified investment in research and development and liberalization of markets" (Howarth 2007, 90).

Besides innovation, the idea of a European Research Area (hereinafter ERA) was one of the main drivers for more R&D at European level since the EC published its Communication "Towards a European Research Area" in January 2000. The Lisbon European Council of March 2000 endorsed this initiative in principle and made the ERA part of its new strategic plan to make the EU to the most competitive, knowledge-based economy in the world. However, the only new instrument that the Council endorsed for implementing these goals was the Open Method of Coordination for benchmarking national R&D policies and in 2008 the financial crisis put the ERA on a lower level of the agenda. Still, the Council of Ministers stated in December 2008 that the ERA should be implemented by 2020 and emphasized once more the importance of coordination and cooperation on a voluntary basis. The ratification of the Lisbon Treaty in 2009 codified the Open Method of Coordination as an official instrument and codifies the establishment of a European Research Area in which researchers, scientific ideas and technology circulate freely.

In spite of the drawbacks in the implementation of the ERA, two other European research institutions were launched in the first decade of the new century: the European Research Council (hereinafter ERC) in 2007 and the European Institute for Innovation and Technology (hereinafter EIT) in 2008. The launch of both institutions was based on very specific understandings of research, technological development and innovation. The ERC is supposed to fund frontier research which is defined as an intrinsically risky endeavour at the forefront of creating new knowledge and developing a new understanding. Frontier research is to pursue questions irrespective of disciplinary boundaries and is to take place in universities, public research institutes and industry laboratories. It is argued that it does not fit in the traditional distinction between basic and applied research but rather may be fundamental research and still maintain a close relation between science and technology.

The EIT, however, is supposed to increase European sustainable growth and competitiveness by reinforcing the innovation capacity of the EU. It is to couple academic research and knowledge production with an entrepreneurial spirit. Thus, in contrast to the ERC, the EIT is allowed to translate research results into commercial innovations. The EIT is based on the concept of the knowledge triangle which assumes that a skilled work force is the basis for undertaking research and development activities, as well as for bringing new products and processes to the market. In return, knowledge and new market developments should have a feedback-loop to educational programmes. Similarly, new knowledge is the source of innovation and in return, new market prospects for innovation can point towards new avenues for research. Thus the concept of the knowledge triangle assumes a non-linear nature of innovation and multiple input and feedback loops between the diverse actors that drive innovation.

In the second decade of the new century the notion of innovation became even more central to European policy. In its “Europe 2020” Communication the European Commission (hereinafter EC) announced to launch seven flagship initiatives to reach its five headline targets: 1) 75% of the population aged between 20-64 should be employed, 2) 3% of the EU’s GDP should be invested in R&D, 3) the 20/20/20 climate/energy targets should be met, 4) the share of early school leavers should be under 10% and at least 40% should have a tertiary degree, and 5) 20 million less people should be at risk of poverty (European Commission 2010a, 5). One of these seven flagship initiatives is the Innovation Union.

The Innovation Union is “to improve framework conditions and access to finance for research and innovation so as to ensure that innovative ideas can be turned into products and services that create growth and jobs” (European Commission 2010a, 5). The underlying notion of innovation is well illustrated in the innovation union communication and relies on three pillars: 1) “focusing on innovations that address the major societal challenges identified in Europe 2020”, 2) “pursuing a broad concept of innovation” and 3) “involving all actors and all regions in the innovation cycle" (European Commission 2011a, 9). The first pillar, for instance, recognizes that innovation might not be good *per se* but that it has to be distinguished between desirable and undesirable developments. In the case of the EU, desirable innovations are those that might contribute to achieve the five headline targets described above. The second and third pillar point out that the EC pursues a broader concept of innovation than the traditional, narrow one that sees innovations primarily as successful products on the market. The process of innovation is to involve diverse actors such as citizens and public research institutes and innovation itself is not only conceived of as novel technological products but also includes organizational improvements in the public sector (European Commission 2011a, 9).

All three pillars are inspired by academic research on innovation and have in turn also triggered novel research as will be illustrated under the next subheading. But before an overview of the academic literature is provided, it is to be outlined how the EC intends to implement the Innovation Union Flagship. Besides the diverse projects funded, the overall measure is, in fact, the application of the open method of coordination. For this purpose, the EC aims at establishing innovation indexes for better comparison among the Member States that are supposed to implement specific national strategies for the achievement of the Europe 2020 headline targets. The progress of the Member States on this way is measured and monitored through the Innovation Union Scoreboard (hereinafter IUS) which provides a comparative assessment of the innovation performance of the EU27 Member States and the relative strengths and weaknesses of their research and innovation systems.

The IUS 2011 distinguishes, for instance, between 3 main types of indicators and 8 innovation dimensions, capturing in total 25 different indicators as the figure beneath illustrates:

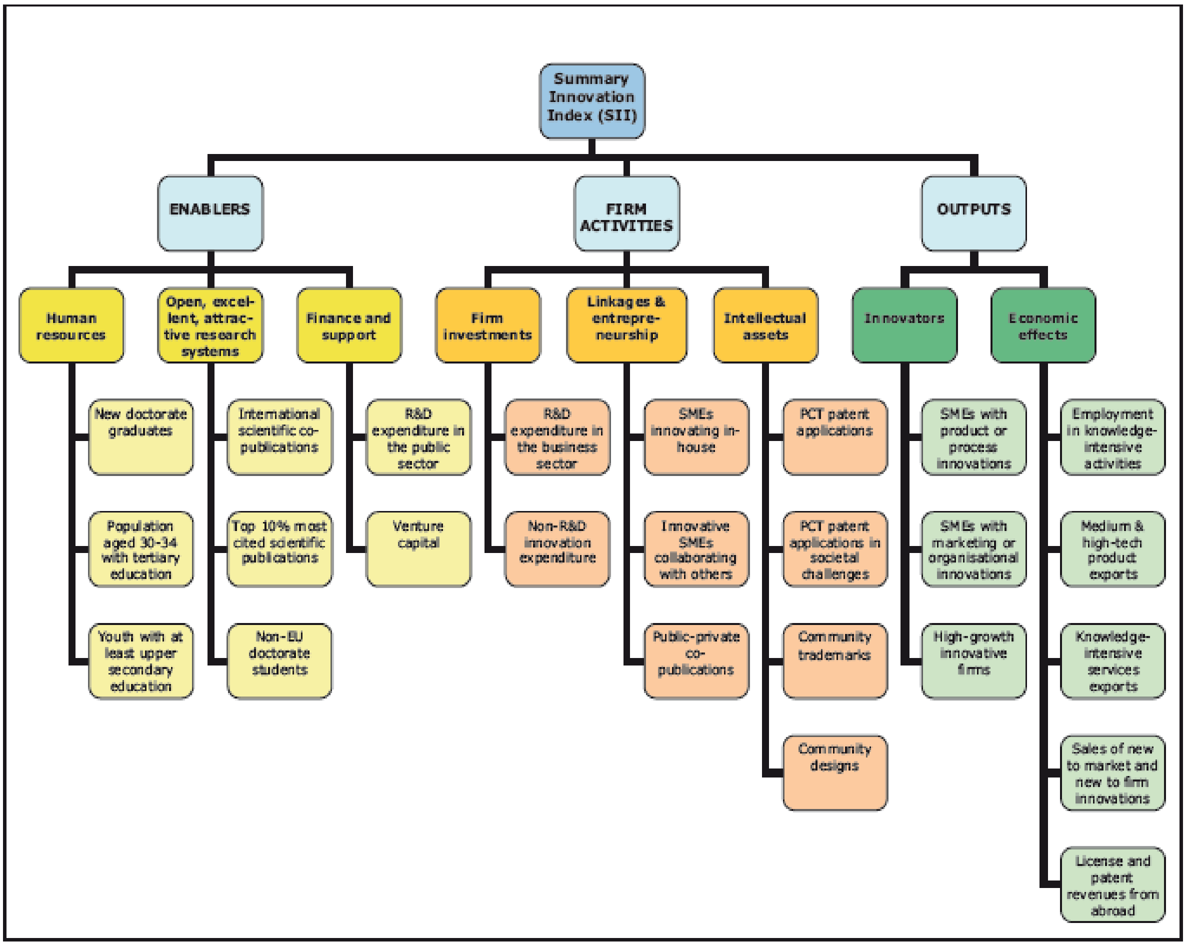



**Figure 1**, The Innovation Union Scoreboard

Source: (European Commission 2012c, 6)

The first of the three main types of indicators are called “Enablers” and are to capture the main drivers of innovation performance external to the firm. The “Enablers” cover 3 innovation dimensions: ‘Human resources’, ‘Open, excellent and attractive research systems’ as well as ‘Finance and support’. The second main type indicator, “Firm activities” is to capture the innovation efforts at the level of the firm that are grouped in 3 innovation dimensions: ‘Firm investments’, ‘Linkages & entrepreneurship’ and ‘Intellectual assets’. Finally, “Outputs” are to cover the effects of firms’ innovation activities in 2 innovation dimensions: ‘Innovators’ and ‘Economic effects’. All together, the 25 indicators are to capture the performance of national research and innovation systems considered as a whole. The data used in the IUS comes from Eurostat and other internationally recognized sources. It serves to rank the Member States according to their innovation performance into four groups: innovation leaders, innovation followers, moderate innovators and modest innovators. This ranking can be used by successful Member States to boost their position in political negotiations (Howarth 2007, 92, 93).

## 2.2 The scholarly literature on EU research and innovation policy

There is no coherent research strand investigating the governance of EU R&I policy and even the overall number of the existing studies is rather small compared to other policy areas. In addition, most of the studies that somehow deal with EU R&I policy do not directly investigate the governance of EU R&I policy. A first group of scholars descriptively traces the historical development of EU R&I policy and the shift of national competences to the European level (Jansen and Semmet 2012; Papon 2009; Tindemans 2009). Above all Jansen & Semmet (2012) provide an in-depth account of the historical development of EU R&I policy from the post-war era in the 1950s to the end of the first decade of the new millennium. In so doing, they trace the development of EU R&I policy along the two main pathways of intergovernmental research organizations and European research institutions. The main point of Jansen & Semmet (2012) is that the development of EU R&I policy has always been the result of the negotiations of the EC and the Member States. Either the EC succeeds in asserting its view of the need of more European research institutions as in 1983 with the launch of ESPRIT, the European Strategic Programme for Research and Development in Information Technology, or the Member States agree upon the need of common research at the European level but refuse to delegate further competences to the EC as in 1985 with the launch EUREKA, the European Research Cooperation Agency (Jansen and Semmet 2012, 17).

In contrast to the Jansen & Semment (2012), Papon (2009) primarily focuses on describing the development of intergovernmental research organizations from the 1950s to the first years of the new millennium. In so doing, he provides an in-depth description of the governance structures of specific intergovernmental research organizations such as the ESA, the European Space Agency, and EUREKA (Papon 2009, 29–34). Also Tindemans (2009) describes the development of EU R&I policy from the post-war era to the turn of the millennium but in contrast to Jansen & Semment (2012) and Papon (2009), Tindemans (2009) includes the development of European education policy in his description. However, all three studies have in common that they mainly focus on providing a descriptive account of the historical development of EU R&I policy and the delegation of national competences to the European level.

A second strand of research highlights the launch or the operation of European research organizations and institutions such as the European Research Council (Kaiser 2012; Luukkonen 2014) and the European Science Foundation (Williams 2012). Kaiser (2012) sheds light on the negotiations that have resulted in the launch of the European Research Council in 2007. Kaiser points out that, while there was a broad consensus on the general need of a European Research Council, there were many different ideas of how the European Research Council should be structured and financed. The EC for instance argued for a strong involvement of national research organizations and funding from the national level, the private sector, and the general EU budget but not from the FP. In contrast, ERCEG, the European Research Council Expert Group established under Danish EU Presidency and composed of scientists and representatives of European research funding organisations, favoured an autonomous European organization funded from the FP. In addition, ESF, the European Science Foundation, suggested to transform itself into an intergovernmental European Research Council funded from the FP. Eventually, the EC agreed to establish the European Research Council as the dedicated implementation structure for the Ideas Programme of FP 7 (Kaiser 2012, 58–60).

Luukkonen (2014) sheds light on the operation of the European Research Council. In Luukkonen's view, the launch of the European Research Council has prompted significant changes in the area of research and innovation in the EU. The European Research Council has for instance strengthened the importance of excellence on the European Research Area agenda and it has quickly gained legitimacy among other European research organizations and enjoys high prestige among researchers and scientists in the EU (Luukkonen 2014, 12). In contrast to Luukkonen (2014), Williams (2012) describes the promotion of basic research in the EU in general. He focuses above all on the European Science Foundation and highlights its importance in the organization of basic research in the EU from its launch in 1975 to its role in the implementation of the European Research Area in the first years of the new millennium (Williams 2012, 37–50). Hence all three studies (Kaiser 2012; Luukkonen 2014; Williams 2012), investigate either the launch or the operation of European research organizations and institutions.

A third group of studies deals with the innovation performance of specific European innovation systems (Köhler et al. 2013), the innovation performance of the Member States (Archibugi and Filippetti 2011; Barbosa and Faria 2011; Rogge and Hoffmann 2010) or with the innovation performance on the regional and local level in the EU (Autant-Bernard, Fadairo, and Massard 2013). Köhler et al. (2013) have applied the sectoral systems of innovation approach to analyze the development of low carbon cars in the EU. Their main conclusion is that the European innovation system for low carbon cars has been effective in developing technologies for the reduction of emissions and that the large resources invested by the original equipment manufacturers in this sector indicate that the prospects for the development of a mass market are quite good (Köhler et al. 2013, 185). Archibugi & Filippetti (2011) have investigated the effects of the economic crisis on the innovation performance of the Member States of the EU. The authors argue that the economic crisis has led to increasing divergence in the innovation performance of the Member States, while the period prior to the economic crisis in the years of 2004-2008 has seen some convergence in the innovation performance (Archibugi and Filippetti 2011, 1153). Barbosa & Faria (2011) have conducted an econometric study of the impact of institutions on innovation in the Member States of the EU. Their main findings are that stringent product and labour market regulation have a negative impact on innovation intensity, while more developed credit markets support the innovation intensity in the respective country (Barbosa and Faria 2011, 1157).

Rogge & Hoffmann (2010) combine insights from environmental economics and the systems of innovation approach in order to analyze the impact of the Emissions Trading System of the EU on the sectoral system of innovation for power generation technologies in Germany. According to the author's findings, the Emissions Trading System of the EU has accelerated the innovation process in general by, among others, driving technology providers' product portfolios towards emission reducing technologies and by triggering German power generators and technology providers to increase their investments in R&I (Rogge and Hoffmann 2010, 7644, 7645). Finally, Autant-Bernard et al. (2013) have analysed the role and the effects of regional innovation policies on localized knowledge spillovers. The authors emphasized the importance of regionally specific innovation policies in order to foster local knowledge generation and innovation (Autant-Bernard, Fadairo, and Massard 2013). Thus all of these investigations belong to a third group of studies that either deals with the innovation performance of specific European innovation systems, the innovation performance of the different Member States or with the innovation performance on the regional and local level in the EU.

In contrast, a fourth strand of research (van der Horst, Lejour, and Straathof 2006; Langfeldt, Godø, Gornitzka, and Kaloudis 2012; Suurna and Kattel 2010) sheds light on the relation between EU and national R&I policies. Van der Horst et al. (2006) have elaborated whether innovation policy should be conducted at the European or at the Member State level. The authors argue that a European innovation policy is more likely to increase public R&D and public funding of private R&D due to economies of scale and external effects. Furthermore, a European innovation policy is to have advantages over national innovation policies in the protection of intellectual property and in the development of standards due to economies of scale. However, as economies of scale and external effects are of a minor importance to the promotion of SMEs, the authors conclude that innovation policy targeted at SMEs is likely to be more efficient if conducted at the national level (van der Horst, Lejour, and Straathof 2006, 3). Langfeldt et al. (2012) have investigated how European and national research efforts interact in order to meet the broader objectives of EU R&I policy on the example of Norwegian research institutions. The authors argue that there is only little coordination between EU and Norwegian research priorities but rather EU research priorities that differ from the Norwegian ones lead to a fragmentation of the research activities in Norway (Langfeldt, Godø, Gornitzka, and Kaloudis 2012). Suurna & Kattel (2010) have analysed the impact of the EU on the innovation policies of the Central and Eastern European countries. In so doing, the authors have highlighted the positive and negative effects that this kind of Europeanization has had on policy-making in Central and Eastern European countries in general (Suurna and Kattel 2010). Hence all of these three studies (van der Horst, Lejour, and Straathof 2006; Langfeldt, Godø, Gornitzka, and Kaloudis 2012; Suurna and Kattel 2010) have shed light on the relation between EU and national R&I policies.

In sum, the preceding paragraphs have briefly outlined four different groups of studies that somehow deal with EU R&I policy but that do not directly highlight the governance of EU R&I policy. In fact, there are only slightly more than a handful of studies that explicitly address the governance of EU R&I policy. Thus it does not come as a big surprise that there are many aspects in the governance of EU R&I policy that have not been investigated, yet. Two salient aspects that have been neglected so far are first the role of expertise in the form of assessments and representations of science and technology in EU R&I policy and second the empirical investigation of the implementation and evaluation of EU R&I policy. This thesis will contribute to closing this gap in research by an empirical investigation of the co-production of policy and expertise on the case of EU H & FC policy and expertise. The main argument is that the governance of EU R&I policy can be best accounted for through an empirical analysis of the simultaneous and interrelated production of policy and expertise. This, however, has not been done yet as the following literature survey will demonstrate.

Reviewing the relevant scholarly literature, the following paragraphs will not only reveal what issues have not been highlighted yet but also indicate why an analysis of the co-production of policy and expertise is needed in order to shed light on them. However, providing an exhaustive overview of the academic literature on innovation in the EU would go beyond the scope of this thesis. Therefore, the following illustrations will be limited to two different disciplinary fields: Public Policy and Science and Technology Studies (hereinafter STS). Furthermore, it should be noted that this summary focuses on European research and innovation policy and not research and innovation policies in the European Union. Rather, this overview will rely upon Public Policy and STS scholars that somehow dealt with European research & innovation policy.

The scholarly literature has been grouped into two categories that outline the two salient aspects that have not been highlighted yet. First, it is to be shown that the role of expertise that is to say the way in which specific technologies are assessed and portrayed in the governance of EU R&I policy has been largely neglected so far. Second, it will be illustrated that there is a lack of empirical investigations of the actual implementation and evaluation of EU R&I policy. The main argument is that both the neglect of theoretical investigations of the role of expertise and the lack of empirical studies of the implementation and evaluation of EU R&I policy can be addressed through a study of the co-production of policy and expertise. A study that both investigates empirically how expertise is produced in concrete research programmes and how it is taken up in the broader policy discourse would address both omissions of the academic literature on the governance of EU R&I policy.

*The neglect of the role of expertise*

The role of expertise in the form of assessments and representations of specific technologies has been largely neglected in the scholarly literature on the governance of EU R&I policy. For instance, a pioneering study of the governance of EU R&I policy was conducted by the political scientist John Peterson in 1991. The author investigates how the Framework Programmes and EUREKA are governed by shedding light on the relation among European

Institutions, the Member States and the industry with an interest-based approach. The European Commission is assumed to be the strongest proponent of a common European R&I Policy as it aims at increasing its competences. By the same token the Member States are supposed to be the strongest opponents, as they want to maintain their authority over R&I policy. The industry can take diverse stances, depending on the specific context. Large enterprises can for instance favour to conduct R&I policy at EU level as environmental groups are predominantly organized at national level and will hence have less power to implement strict environmental standards at EU level.

Apart from these general interest constellations, Peterson's study also brings about more specific findings on the factors that affect the governance of EU R&I policy. The Commission for instance can encourage industry collaboration and ally with industrial actors in order to increase its own power in negotiations with Member States over authority on technology policy (Peterson 1991, 276). Huge member states can be interested in R&I that supports their national champions while small Member States without any national champions could favor R&I that is focused on SMEs (Peterson 1991, 281, 282). Furthermore, common European R&I initiatives can be encouraged by individual Member States that have an interest in preventing other Member States of R&I collaborations with non-EU Member States (Peterson 1991, 278).

Hence Peterson (1991) provides a good illustration of the main actors involved in the governance of EU R&I policy and their converging and diverging interests. However, he does not address the potential role that expertise might play. It is for instance easily conceivable that the way in which scientific progress and technological development are portrayed in political discussions might affect the interests of the actors involved. Papon, a professor of physics, claims that the creation of large European research organizations in the 60s and 70s was triggered by the idea of "Megascience" which implied the belief that the EU can only be competitive at an international level through the pooling of resources and large-scale research in specific areas (Papon 2009, 25–28). Thus the perceived need of large-scale research for scientific progress made the Member States more prone towards scientific cooperation at the European level. Of course, it is also conceivable that this idea of "Megascience" did less reflect the actual situation of science and technology but rather was created out of political considerations in order to be used as an argument for more European research. Either way the potential relevance of expertise in the form of assessments and representations of science and technology in the governance of EU R&I policy becomes apparent.

The study of Peterson (1991) remained the only one that explicitly addressed the governance of EU R&I policy until the turn of the century when the increased importance of the notion of innovation attracted the attention of several scholars. First, Sanz-Menendez & Borrás (2000) argued that significant changes in the governance of EU R&I policy have occured due to a shift from a frame of science policy to technology policy and then to innovation policy (Sanz-Menendez and Borrás 2000, 1). In fact, the constructivist approach of Sanz-Menendez & Borrás constitutes the first study that actually sheds lights on the role of expertise in the form of representations of science and technology in the governance of EU R&I policy. The authors investigate how ideas of the role of science and technology in society and economy have changed over time and how the way in which innovation and technology are related to other political issues such as competitiveness, job-creation, economic growth and social progress affects the governance of EU R&I policy (Sanz-Menendez and Borrás 2000, 1).

A further notable aspect of the study of Sanz-Menendez & Borrás is that they not only highlight how the perception of science and technology affects the political discussions but also how these ideas came into being. For this purpose, the authors take a look at the expert communities in the science and technology policy domain that have fed the new ideas on science and technology into the broader policy discourse (Sanz-Menendez and Borrás 2000, 5). Knowledge-making on the situation of science and technology in the EU increased considerably in the 70s when several EU funded projects triggered "the development of a RTD policy analysis community that was able to supply new data, studies and ideas for S&T issues in Europe" (Sanz-Menendez and Borrás 2000, 9). Sanz-Menendez & Borrás also indicate that the expertise produced is not independent of the political situation at the time being on the example of the Aigrain Report from 1989. The report evaluated the Framework Programmes and criticized that these are too industry-oriented and that they should pay more attention to the scientific and academic bases of the EU. Hence Sanz-Menendez & Borrás interpret the report as “mainly a reaction against the dominance of big firms’ interests” (Sanz-Menendez and Borrás 2000, 11).

Sanz-Menendez & Borrás also explain the shift from research to innovation policy as a result of the expertise created through evaluations of the Framework Programmes and other EU funded projects. A recurrent argument in the reports produced was that EU R&I policy too much only caters the needs of the science and technology community and too little actually directs its efforts. The idea was that the economic benefits of technological breakthroughs stem from an adequate embedding of the technology in the society and not merely from the funding of technology development. Hence EU R&I policy should be linked to other EU policies and become more innovation-oriented that is to say more oriented towards technology diffusion (Sanz-Menendez and Borrás 2000, 12, 13). In fact, Sanz-Menendez & Borrás argue that the shift towards innovation policy resulted from the common production of knowledge of experts and policy-makers: “The gradual development of this new empirical knowledge about S&T policies and new normative rationale have had an impact on policy making via the role played by experts in OECD, national and Commission forums. The communication and dialogue between experts and bureaucrats has been so close and intense that the new frame has developed in a rather interactive way” (Sanz-Menendez and Borrás 2000, 14).

Thus the importance of the study of Sanz-Menendez & Borrás (2000) cannot be underestimated as it remains the only one pointing out the mutual impact of policy and expertise on each other in the governance of EU R&I policy. Two further studies of the political scientist Susana Borrás deal in somewhat different veins with the governance of EU R&I policy. Borrás (Borrás 2004) elaborates theoretically whether it is possible to conceptualize the development of the EU in general as a system of innovation and Borrás

(Borrás 2009) suggests how the efficiency of the governance of systems of innovation could be assessed and evaluated. Cagnin et al. (Cagnin, Amanatidou, and Keenan 2012) also elaborate theoretically how the development of European innovation systems could be directed towards broader societal challenges. In another study Borrás (2003) mostly confirms her argument that EU R&I policy has shifted from technology to innovation policy and no longer only aims at supporting specific technologies but rather at generating positive frameworks for innovations (Borrás 2003, 4). In addition, she suggests four main aspects that any investigation of the governance of EU R&I policy should consider: 1) Europeanization: the current division of tasks between the EU and member states, 2) Internationalization: the current international arrangements and the EU action (or not) as a unitary actor, 3) The changing nature of public and private realms, 4) Disparities and diversity within the EU (Borrás 2003, 21).

In summary, the illustrations above have clearly shown that the role of expertise in the form of assessments and representations of science and technology in EU R&I policy has been largely neglected. Only the study of Sanz-Menendez and Borrás (2000) constitutes a first effort in highlighting this issue and calls for more in-depth analyses of empirical examples.

*The lack of empirical investigations of the implementation and evaluation of EU R&I policy*

There are only few studies that have shed light on the implementation and evaluation of EU R&I policy on the basis of empirical examples. Stefan Kuhlmann (2001) for instance speculates on the further development of EU R&I policy with regard to the implementation of research projects. Kuhlmann is a political scientist by training but has situated himself in the STS community over the years and most of his contributions target the STS community as well. In his article he starts from the point of view that national contexts dominated the implementation of research projects funded by the EU until the turn of the century. However, against the background of increasing European economic integration and growing diversification in regional, national and European innovation policy, Kuhlmann speculates on the further development of the implementation of EU R&I policy (Kuhlmann 2001, 953, 954).

The author develops three scenarios for a future implementation of EU R&I policy and assesses the chances for their realization. The first scenario of a centralized EU R&I policy with the EC as the key actor is deemed to fail according to the author due to an overload of policy complexity and the resistance of the Member States and national research institutes. In contrast, the author regards the second scenario of a decentralized European R&I arena with open competition between national and regional innovation systems as more likely. Yet, this scenario bears the risk of a widening socio-economic gap as regions and Member States with lower innovation capabilities might fall behind. However, the author sees also some degree of probability for the third scenario of a mixture of competition and cooperation between national and regional innovation arenas which is centrally mediated by European institutions. The author interprets the EC Communication on the European Research Area (European Commission 2000a) as a first step in this direction (Kuhlmann 2001, 972).

Kuhlmann's contribution indicates that the concrete implementation of EU R&I policy can differ significantly from the more general formulation of its overall objectives. The implementation of EU R&I policy in research projects is about setting concrete research priorities, about taking decisions upon the acceptance or rejection of project proposals for funding, and about the cooperation of industrial, political and scientific actors in research activities. However, Kuhlmann's study remains an outlook on the theoretical level based, of course, on general assessments of past Framework Programmes but without any empirical grounding in the sense of concrete data on the implementation of EU research projects. In fact, rather than being an exception, the study reflects the general lack of empirical investigations of EU R&I policy. There is for instance a group of scholars who theoretically elaborate whether EU R&I policy increases cross-border cooperation among scientists (Edler and Kuhlmann 2012; Luukkonen and Nedeva 2010; Nedeva 2013). However, these studies remain on the theoretical level arguing for a broader notion of integration in EU R&I policy that not only looks at the shift of competences to the European level but also at the actual interaction of scientists in EU funded research projects.

Drilling down empirically, Hervás Soriano & Mulatero (2011) and Rodriguez et al. (2013) look at the factors that affect the implementation of EU R&I policy on the empirical example of the EU Framework Programmes. Hervás Soriano & Mulatero (2011) highlight the role of the Strategic Energy Technology Plan (hereinafter SET Plan) of the EC for the development of renewable energies with respect to the strategic approach, the degree of policy integration, governance and financing. The authors argue that the SET Plan was successful in providing guidance and in mobilizing and coordinating actors as it set the objectives for 2020, ensured the consistency with the long-term targets for 2050 and as it established criteria for the selection of technologies through techno-economic analysis and a wide consultation of actors (Hervás Soriano and Mulatero 2011, 3589). The SET plan also helped to integrate diverse policy initiatives that aim at fostering the development of renewable energy technologies and to coordinate them as the SET plan created a steering mechanism and information system (Hervás Soriano and Mulatero 2011, 3584, 3585). This information system is an open-access platform for the exchange of technical data which is managed by the Joint Research Centre of the EC in cooperation with a broad range of stakeholders (Hervás Soriano and Mulatero 2011, 3587). Furthermore, the authors argue that the SET plan shifted the focus from cooperation of Member States on specific projects to joint design and execution of whole research programs (Hervás Soriano and Mulatero 2011, 3585, 3586).

Hence the study of Hervás Soriano & Mulatero (2011) provides an example of how broader EU R&I policy goals are reflected in the set-up and management of more concrete research projects and programmes. In fact, they point out the importance of intermediate instruments such as the SET Plan which bridge the gap from more abstract EU energy and environmental policy goals to the funding of specific technologies that might contribute to the achievement of these goals in the future. Also the study of Hervás Soriano & Mulatero provides a thorough overview of the landscape of EU R&I initiatives and projects on renewable energies that have been launched in recent years (Hervás Soriano and Mulatero

2011, 3583). However, their study remains unidirectional in the sense that it only sheds light on how macro-level policy goals are reflected in the implementation of EU R&I projects while it does not highlight how the implementation and evaluation of these projects is fed back onto the political macro-level. Again, this appears to be a question of the role of expertise in EU R&I policy. One might wonder for instance how the assessment of technological progress in EU research projects on alternative energy technologies affects the broader discussions on EU energy and environmental policy which build on these technologies.

Rodriguez et al. (2013) similarly shed light on the integration of broader societal issues into the Framework Programmes in a unidirectional manner. They investigated in how far 1) industrial, 2) socio-economic, 3) socio-ethical and 4) stakeholder issues are included in research solicitations in FP 5, 6 and 7. They analyzed nearly 2500 research solicitations from areas in which the integration of socio-technical aspects is supposed to be particularly relevant such as the life sciences, energy research and nanotechnology and assessed for each solicitation whether or not it includes any form of socio-technical integration (Rodríguez, Fisher, and Schuurbiers 2013, 1127–1130). Their main result is that overall socio-technical integration has clearly increased over time. This refers to both the quantity and the quality of the integration. While the quantity denotes the total number of solicitations that include requests for integration, the quality means that integration is not only written in the solicitation but actually also incorporated into the research activities (Rodríguez, Fisher, and Schuurbiers 2013, 1131, 1134). However, in spite of this general increase in integration, differences between the diverse categories are considerable. While socio-ethical and stakeholder integration taken together have decreased from 40% of the total requests for integration in FP 5 to 28% in FP 7, socio-economic and industrial integration have risen from 60% to 72% in the same period of time (Rodríguez, Fisher, and Schuurbiers 2013, 1132).

Hence Rodriguez et al. (2013) have highlighted the relevance of broader societal issues in the implementation of EU R&I policy. They have shown that there is an increasing tendency to frame research projects in socio-economic and industrial terms. However, the study of Rodriguez et al. (2013) does not ask whether this development is accompanied or even triggered by a parallel shift in the overall political debates towards industry- and market-oriented research and innovation. Furthermore, the study does not illustrate in how far this socio-economic and industry framing of research solicitations actually affects the decisions of policy-makers upon approval for funding. An empirical investigation of the co-production of policy and expertise could shed light on these issues by highlighting how the framing of specific technologies by experts impacts the political decisions upon financial support for these technologies. Simultaneously, a study of the co-production of policy and expertise could illustrate how the overall political discussions actually impact how experts frame and portray specific technologies.

## 2.3 Conclusions

This chapter was to illustrate the scientific relevance of a study of the co-production of European Union hydrogen and fuel cell policy and expertise. For this purpose, the first part of this chapter focused on outlining the wider context of European research and innovation policy as hydrogen and fuel cells (hereinafter H & FC) constitute one of many technologies that are promoted through the Framework Programmes of the EU. Therefore, the historical development of European research and innovation policy (hereinafter EU R&I policy) and its present state was explained in detail. First, however, it has been outlined that there are many different understandings of the notion of innovation and of the processes that lead to innovation. The historical development of EU R&I policy from the 1950s up to the present day has always relied on specific understandings of the relations between research, technology development, and innovation. Most recently, the Lisbon Council of March 2000 with its strong focus on innovation has brought about a radical shift in EU R&I policy. Consequently, new European research organizations such as the European Research Council and the European Institute of Innovation and Technology were launched based on new understandings of research and innovation. Also the second decade of the new millennium saw an increased importance of innovation in EU policy with the Innovation Union being one of the seven Flagship Initiatives that altogether are to achieve the objectives of the Europe 2020 agenda.

The second part of this chapter was dedicated to illustrating the research gap in the scholarly literature on the governance of EU R&I policy. For this purpose, the few studies from the two fields of Public Policy and Science and Technology Studies that have investigated the governance of EU R&I policy have been outlined. In so doing, two salient issues that the scholarly literature on the governance of EU R&I policy has not taken into account, yet, have been pointed out. First, the role of expertise in the form of specific understandings of science and technology has been largely neglected by the scholarly literature so far. Second, most studies of the governance of EU R&I policy remain on the theoretical level so that there is a lack of empirical investigations of the implementation and evaluation of EU R&I policy. Both issues, the neglect of the role of expertise and the lack of empirical investigations, could be addressed through a study of the co-production of EU H & FC policy and expertise that would contribute to filling this gap in research on the governance of EU R&I policy.

This thesis sheds light on the role of expertise in the governance of EU R&I policy by highlighting how policy and expertise are co-produced in the promotion of hydrogen and fuel cell technologies in the EU. The main assumption is that policy and expertise are not produced independently of each other but rather in parallel and in relation to each other. Consequently, this thesis investigates the co-production of EU H & FC policy and expertise. In so doing, this thesis also constitutes one of the few studies that examine the governance of EU R&I policy on the basis of a concrete empirical case. By highlighting the promotion of hydrogen and fuel cell technologies in the EU it will be illustrated how EU R&I policy is implemented and evaluated in a concrete empirical case. In sum, through studying the co-production of EU H & FC policy and expertise, this thesis is to contribute to filling the gap in research on the governance of EU R&I policy that was outlined in this chapter. For this purpose, the next chapter explains the innovative theoretical framework that was developed for the analysis of the co-production of EU H & FC policy and expertise.

# 3 The co-production of policy and expertise

This chapter outlines the theoretical framework of this thesis which is to contribute to filling the gap in research on the governance of EU R&I policy illustrated in chapter 2. For this purpose, a framework is developed that allows addressing the role of expertise in the governance of EU R&I policy on the theoretical level and that simultaneously enables an empirical investigation of the dynamics that characterize the implementation and evaluation of EU R&I policy. Hence the added value that this thesis contributes to the scholarly literature on the governance of EU R&I policy lies in highlighting the role of expertise in addition to the usual factors taken into consideration. It does so by elaborating how public policy approaches aiming at the explanation of policy development from agenda-setting to evaluation can be supplemented by an analysis of expertise.

Thus the main theoretical innovation of this thesis is to provide a theoretical framework for the simultaneous analysis of policy and expertise. For this purpose, both the development of policy and of expertise will be located at the meso-level of the policy subsystem. The basic assumption is that both policy and expertise are produced within the same policy subsystem but within separate discourses. In addition to the usual policy discourse it is assumed that there is an expertise discourse led by partly the same actors but producing a different outcome. While the policy discourse produces policy outputs, the expertise discourse produces expertise in the form of widely accepted representations of H & FC. Of course, both discourses are highly interrelated with considerable overlapping. Therefore, the main objective of this chapter is to provide a theoretical framework for the analysis of the relation between these two discourses which lies at the heart of the co-production of policy and expertise.

Each of the following subchapters contributes a specific part to the development of the overall theoretical framework. First, the idea of co-production is introduced in the first subchapter. Co-production implies that there are two interrelated issues produced in parallel: policy and expertise. Second, subchapter 3.2 explains the policy cycle model which will be used as a heuristic device in the analysis of the co-production of EU H & FC policy and expertise. Thereafter, subchapter 3.3 compares diverse meso-level public policy approaches highlighting their strengths and weaknesses. One of these weaknesses is the only implicit treatment of expertise. Therefore, subchapter 3.4 draws upon other strands of research and points out their most important insights in the study of expertise. Subsequently, subchapter 3.5 outlines a co-productionary framework for the analysis of EU H & FC policy and expertise synthesizing the main arguments made in the previous subchapters. Finally, subchapter 3.6 sums up the most important insights of this chapter and provides an outlook on the further proceedings of this thesis.

## 3.1 The idea of co-production

This thesis applies a very specific understanding of the notion of co-production which is not consistent with its usual use in the scholarly literature. To provide the reader with a better understanding of the usual application of co-production the following paragraphs are to illustrate some of its more prominent applications. Thereafter, it is outlined how the idea of co-production is conceived of in this thesis.

In fact, while the idea of co-production is a rather new one, the notion of co-evolution has been used for the investigation of the intersection among two or more different societal areas such as science, politics or economy in diverse scientific studies under differing headings. Scholars in the field of Science and Technology Studies have for instance imported the notion of co-evolution from the natural sciences in order to analyze “the interaction process between different systems (-elements) through which these adapt to one another” (Loorbach 2007, 55). The underlying assumption is that there are diverse societal systems that adhere to their own logics but that are not entirely independent of each other. Rather, these diverse systems do not only develop according to their internal dynamics but also through adaption to the developments in other systems (Loorbach 2007, 55, 56).

Hence the notion of co-evolution is applied to highlight the intersection among diverse societal areas and to explain their mutual impact on each other. Etzkowitz and Leyesdorff (2000) have for example used the notion of co-evolution to investigate the overlapping institutional sphere among academia, industry and state in their triple helix model. They describe the relations among the three spheres as an endless transition with complex, non-linear dynamics. Ongoing transformations within one area occur under the pressure of altered conditions in another area. If two areas increasingly shape each other, this co-evolution may lead to more stabilized, adjusted conditions in both areas (Etzkowitz and Leydesdorff 2000, 113, 114).

In contrast to the triple helix model, Sheila Jasanoff (2004) prefers a more agency-based terminology. For this purpose, she has introduced the idea of co-production in order to emphasize that the social and the natural world are produced together. According to her, co-production should not be conceived of as a consistent theory but rather as an idiom; “a way of interpreting and accounting for complex phenomena” (Jasanoff 2004b, 3). The aim of co-production research “is to explore how knowledge-making is incorporated into practices of state-making, or of governance more broadly, and, in reverse, how practices of governance influence the making and use of knowledge” (Jasanoff 2004b, 3). In this vein, diverse scholars have studied the mutual impact of policy-making and knowledge-making on each other (e.g. Lövbrand 2011; Waterton and Wynne 2004). Furthermore, the co-productionist idiom has been used to analyze the emergence and stabilization of the framing of new technologies (Jasanoff 2004a, 38).

This thesis builds on this work of Sheila Jasanoff (2004) in order to highlight how EU H & FC policy and expertise are co-produced. To put it in Jasanoff’s words: This thesis is to explore how expertise-making is incorporated into practices of policy-making and, in reverse, how practices of policy-making influence the making of expertise. Thus the idea of co-production is not used to highlight the intersection among diverse societal areas as it is done in most of the scholarly literature. Rather, co-production is applied in a much narrower sense to investigate the simultaneous development of policy and expertise in one and the same policy subsystem.

## 3.2 Public policy according to the model of the policy cycle

This subchapter explains the policy cycle model that will be used as a heuristic device in the analysis of the co-production of EU H & FC policy and expertise. The main assumption of the policy cycle model is that the policy process can be split up into the five different stages of 1) agenda-setting, 2) policy formulation, 3) decision-making, 4) policy implementation, and 5) policy evaluation (Howlett, Ramesh, and Perl 2009, 12, 13). Each of these stages is characterized by different dynamics and different outcomes as will be explained in more detail in the following paragraphs. First, however, it has to be clarified that these different stages should rather be conceived of as ideal types than as accurate descriptions of the reality. This means that there are no clear-cut boundaries between the different stages and that the specific dynamics of the different stages can occur at the same time. If this is kept in mind, however, the policy cycle model constitutes a useful heuristic device for the interpretation of the policy process as it allows pointing out those issues that have shaped the policy process more than other ones at a specific period in time. It is in this way that the policy cycle model will be used in this thesis.

The stage of agenda-setting denotes the process in which a certain issue attracts the attention of the government authorities. This includes above all the articulation of a social problem that requires an intervention by public policy (Jann and Wegrich 2003, 83). Furthermore, one has to distinguish among the public agenda that consists of the media and experts and the informal and formal political agenda (Jann and Wegrich 2003, 83). Issues can be discussed heavily in the media but may never reach the political agenda if there is no widespread belief for the necessity of an intervention by public policy. It can also be expected that the range of issues discussed on an informal basis by policy-makers is much wider than the problems that finally reach the formal political agenda.

Policy formulation can be defined as the process in which all available options and proposals are defined, considered and narrowed down to those acceptable to policy-makers (Howlett, Ramesh, and Perl 2009, 110). This process starts of course with the definition of the policy objectives desired before potential opportunities for action can be discussed (Jann and Wegrich 2003, 85). Subsequently, deliberations about what solutions to a problem are considered to be feasible and which are not take place (Howlett, Ramesh, and Perl 2009, 110). Hence, the importance of policy formulation cannot be underestimated as already at this very early stage of the policy cycle model certain options are ruled out and not even considered in the next stage.

Decision-making denotes the process in which formal decisions are taken and thus involves only those politicians, judges, and government officials empowered to make authoritative decisions in the area in question (Howlett, Ramesh, and Perl 2009, 140). Therefore, the adoption of a certain policy option relies among others on the distribution of competences among diverse political institutions (Jann and Wegrich 2003, 87, 88). In the complex governance structure of the EU for example the European Commission, the European Parliament and the Council of the European Union are the three most important decision-making bodies. However, one must not forget that formal decisions are preceded by informal negotiation processes in which also actors without a formal position in government authorities are involved such as for instance interest groups (Jann and Wegrich 2003, 86).

The stage of policy implementation refers to the realization of the policy programme adopted by the institutions and organizations in charge (Jann and Wegrich 2003, 89). This includes a range of tasks such as the concretization of the programme in order to clarify how it is to be applied, the allocation of resources to determine who is to implement the programme and decisions about how to apply the general programme adopted to concrete cases (Jann and Wegrich 2003, 90). These processes are affected by diverse factors such as the nature of the problem, the general context including social conditions, economic conditions, technology and political circumstances, the administrative apparatus, the political and economic resources of the target group as well as the public support (Howlett, Ramesh, and Perl 2009, 161-163, 173-176).

Finally, diverse types of policy evaluation can be distinguished. Howlett et al. (2009) speak of administrative evaluation that is undertaken by government agencies in the effort to minimize costs, judicial evaluation that is carried out by the judiciary and concerned with possible conflicts between government actions and constitutional provisions or individual rights and political evaluation that is undertaken by anyone with a political motivation to either label a policy a success or failure (Howlett, Ramesh, and Perl 2009, 185-189). Jann & Wegrich add a fourth type of policy evaluation undertaken by political scientists that investigate whether a programme achieved the intended results or not (Jann and Wegrich 2003, 92).

These illustrations should provide a brief insight into the logics of model of the policy cycle that is to be applied to describe and analyze European Union hydrogen and fuel cell policy in this thesis. However, it should also be noted that the model has to be approached carefully as it indirectly assumes a functionalist logic of applied problem-solving which is not the case in reality. In fact, the different cycles maybe hard to separate from each other as for example agenda-setting and decision-making can occur almost simultaneously in very short periods of time. Bearing these shortcomings in mind, however, the model can be a helpful tool to identify the specific dynamics that characterize specific periods of time in the policy process. Therefore, the policy cycle model will be used as a heuristic device in this thesis in order to make sense of the complex phenomenon of the co-production of EU H & FC policy and expertise.

## 3.3 The implicit treatment of expertise in meso-level public policy approaches

The primary aim of meso-level public policy approaches is not to explain the production of expertise but rather the development of public policy. Hence expertise is only ascribed a minor role in these theories and is usually included in the form of external factors or conditions. In fact, expertise is often mentioned as one among other relatively stable, external parameters that play a role in political debates such as socio-economic conditions, the historical context and the physical nature of a public problem. This means that the impact of expertise on political discussions is taken into account but only in a unidirectional way. Although not explicitly stated in that way, this treatment of expertise suggests a problematic view on the provision of expert information to policy-makers. Many meso-level public policy theories treat expertise as given scientific information and do not look at its production. This can suggest that expertise was developed in an isolated context independent of the political debate into which it is fed as a relatively stable, external condition later on.

In contrast, this thesis claims that the simultaneous analysis of policy and expertise and their mutual impact on each other can provide an additional explanatory value in highlighting the development of public policy. Thus the main idea is to make the production of expertise explicit and to integrate it into a meso-level public policy approach. However, this is not to say that any production of expertise is to be included into the theoretical framework but rather only those on the policy issue in question. Hence this thesis will only investigate the production of expertise on H & FC, while it will not consider how other expert information such as for instance forecasts on oil prices or climate change have been developed. These information are of course important for the debate on H & FC, yet, they are produced by other actors outside of this policy subsystem. Consequently, this thesis presents a theoretical framework that allows the investigation of the co-production of policy and expertise on specific policy issues while information from other political or scientific debates will be included as given external factors.

Three meso-level public policy approaches are illustrated and compared in the following paragraphs: 1) Advocacy Coalition Framework, 2) Policy Narrative Framework, and 3) Discourse Coalition Approach. In addition to the general features of the approaches being explained, a particular focus is paid to their treatment of expertise on the issue in question. It is not only shown what role expertise plays in the approaches but also indicated how each of them could benefit from an integration of the production of expertise into the policy subsystem. In so doing the additional explanatory value of a theoretical framework for the analysis of the co-production of policy and expertise is highlighted. After this comparison of the three meso-level public policy approaches, the concept of the policy entrepreneur is introduced as a useful means to account for the influence of individual actors in the policy subsystem. For this purpose, it is elaborated how the concept of the policy entrepreneur supplements the three meso-level public policy approaches. Finally, at the end of this subchapter it is concluded that the Discourse Coalition Approach in combination with the concept of the policy entrepreneur is most suitable for an integration of the production of expertise into the general theoretical framework which is why it is to be applied in this thesis.

*Advocacy Coalition Framework*

The figure beneath outlines how public policy operates according to the Advocacy Coalition Framework:

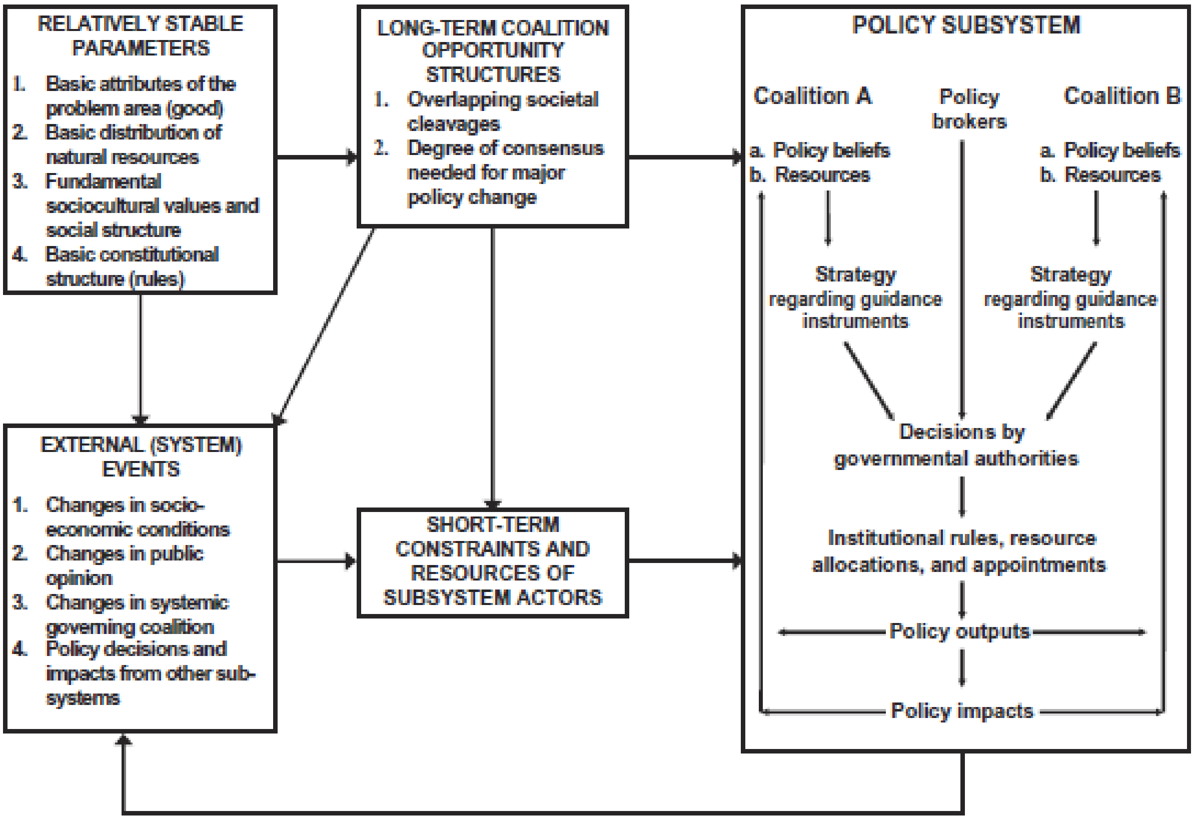



**Figure 2**, The Advocacy Coalition Framework

Source: (Weible, Sabatier, and McQueen 2009, 123)

The basic assumption of the Advocacy Coalition Framework (hereinafter ACF) is that while political decisions are formally made on the macro-level they are prepared and negotiated on the meso-level of the policy subsystem where all actors with interests at stake can be aggregated into advocacy coalitions (Sabatier and Weible 2007, 192). Advocacy coalitions are composed of various private and public actors who work together over time on the basis of shared normative and causal beliefs in order to influence the course of a policy subsystem (Sabatier 1998, 102, 103). Three types of beliefs have to be distinguished: While deep core beliefs are fundamental and universal values such as views on liberty and equality, policy core beliefs refer to the level of the subsystem and to issues such as the proper role of the general public or the causes of policy problems (Sabatier and Weible 2007, 194–196).

Furthermore, policy core beliefs contribute to the stability of advocacy coalitions as they are relatively stable over time and can only change through “gradual accumulation of evidence” (Sabatier 1998, 104). Finally, secondary beliefs are directly related to a specific proposal or suggestion (Sabatier and Weible 2007, 194–196). These policy beliefs determine together with the coalitions resources such as for instance information, budgets and formal legal authority the strategy that a coalition employs in order to influence policy-makers on the macro-level (Sabatier and Weible 2007, 201–203).

In fact, the precise definition of what a coalition is and who belongs to it is one of the main strengths of the ACF. Above all the focus on concerted actions provides a clear criterion for determining coalition membership in practice. Actors as different as NGOs, large private enterprises, governmental organizations, public research institutes, or SMEs can be part of one and the same advocacy coalition provided that they actually cooperate with each other and coordinate their actions to promote a specific issue in common. Thus the ACF allows drawing a clear line between different coalitions in a policy subsystem and analyzing how the concerted actions and strategies of a specific coalition impact the further course of the policy subsystem. This impact, of course, depends not least on the resources available to the different members of a coalition and the willingness to invest these resources to promote the issue in question.

However, while the focus on concerted actions provides a clear criterion for determining coalition membership in practice, identifying the different types of policy beliefs in a concrete empirical case might prove to be somewhat more problematic. As explained above, policy beliefs constitute a very central concept in the ACF and serve as the main explanation for actor behaviour and coalition formation. In a nutshell, actors act on basis of their beliefs and form coalitions with actors who share these beliefs. In practice, however, it is somewhat problematic to prove that specific actions actually rely on certain beliefs and do not just constitute some form of strategic behaviour. While concerted actions provide a clear criterion for determining coalition membership, explaining actor behaviour on the basis of policy beliefs risks attributing false motivations to certain actions. To avoid this risk of imposing certain beliefs to specific actors that might not exist in practice, two more constructivist meso-level public policy approaches will be considered in the following two subheadings. First, however, the potential of the ACF for analyzing the role of expertise in the policy process will be elaborated in the following paragraphs.

The figure above illustrates that the ACF does not directly address the role of expertise in the development of public policy but rather expertise could be suspected in diverse components of the ACF. It is for instance easily conceivable that policy-makers commission the development of scientific reports to elucidate the issue they are dealing with. In that case, expertise could be located under the relatively stable parameter “basic attributes of the problem area (good)”. Thus the ACF would allow for an investigation of the influence of expertise on the policy subsystem but it would not allow highlighting the influence of the political debate on the production of expertise. This is because the production of expertise would be situated outside of the policy subsystem suggesting independence from the political discussions.

It would also be possible to locate expertise inside of the policy subsystem under a coalition’s resources. Expertise in the form of expert information could be one among other resources such as legal authority or financial means. This would allow investigating how expertise is interpreted and used according to specific policy beliefs. It would allow tracking how changing expertise is embedded into the political discussions over time. However, this treatment would still remain a unidirectional one as it would not take into account any political influence on the production of expertise. Hence the ACF allows identifying how expertise affects the political discussions over time but it is not well suited for an investigation of the co-production of policy and expertise.

Yet, it is precisely this co-production of policy and expertise that could provide an additional explanatory value for the development of the policy subsystem. The main point is that expertise can only be produced inside of the policy subsystem as this explicitly includes all actors dealing with a specific policy issue. Expertise can only be developed by actors that are very familiar with a specific policy issue and thus by definition part of the policy subsystem. This in turn makes it obvious that there cannot be any clear-cut separation between policy and expertise as both are produced by the same actors inside of the policy subsystem. Instead there are two different discourses on policy and expertise which are highly interrelated and led by the same actors. A study of the co-production of policy and expertise could highlight the mutual impact of these two discourses on each other and show in how far political objectives affect the development of expertise and in how far novel expert information can change political preferences.

*Policy Narrative Framework*

Shanahan et al. attempted to develop the ACF further and adjusted it to a more constructivist perspective as outlined in the figure beneath:

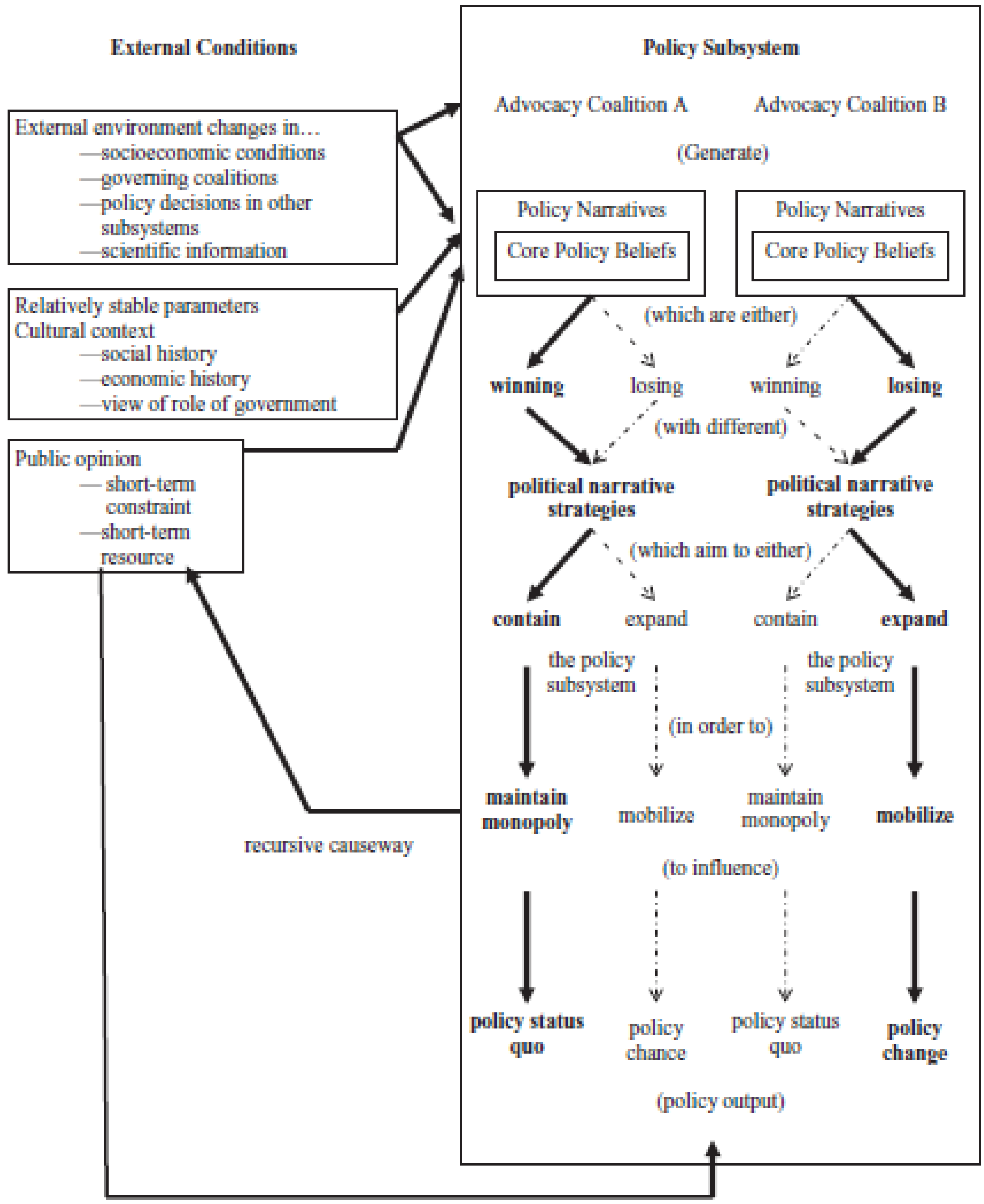


**Figure 1.** Narrative Policy Framework Meso-Level Perspective of ACF.

**Figure 3**, The Policy Narratives Framework

Source: (Shanahan, Jones, and McBeth 2011, 543)

Shanahan et al. (2011) provide a good illustration of how a more constructivist approach that centres on narratives could be integrated into the ACF while maintaining the central role of policy beliefs in the overall framework which are to be shaped by the cultural context that is to say the social and economic history and the view of the role of the government

(Shanahan, Jones, and McBeth 2011, 542). Policy narratives consist of a plot, characters (hero, villain, and victim) and aim at rising support for a desired policy outcome (Shanahan, Jones, and McBeth 2011, 539). They are created by stakeholders who “use words, images, and symbols to strategically craft policy narratives to resonate with the public, relevant stakeholders, and governmental decision makers, with the aim of producing a winning coalition” (Shanahan, Jones, and McBeth 2011, 536). Therefore, Shanahan et al. (2011) argue that the constructivist dimension in public policy is best accounted for by analyzing policy narratives as these constitute a means for communicating policy beliefs and organizing policy information (Shanahan, Jones, and McBeth 2011, 536, 540).

Shanahan et al. also emphasize the role of narrative strategies for the further course of the policy subsystem. Coalitions can choose to portray themselves either as winning or losing in order to maintain the policy status quo or to change it. While “a “winner’s tale” constructs a story that seeks to preserve the status quo, whereas a “loser’s tale” seeks policy change” (Shanahan, Jones, and McBeth 2011, 544). Groups that choose to portray themselves as winning attempt to restrict participation by narrowing the scope of the conflict while groups that choose to portray themselves as losing attempt to mobilize further actors and to widen participation in the issue in question (Shanahan, Jones, and McBeth 2011, 544). For this purpose, groups that portray themselves as losing concentrate benefits of the opposed policy solution on a small group of actors in their narratives while they diffuse the costs to the broad majority. Likewise, coalitions that portray themselves as winning diffuse the benefits of their preferred policy solution to a broader group of actors in their narratives while they concentrate the costs on a small minority (Shanahan, Jones, and McBeth 2011, 544).

The figure above shows that, in contrast to the ACF, the Policy Narratives Framework (hereinafter PNF) directly addresses the impact of expertise as “scientific information” in the category of external conditions. Although still situated outside of the policy subsystem, the PNF ascribes an important role to expertise in the policy-making process as it assumes that new scientific information have to be integrated into the political debate where they can alter policy beliefs and thus trigger policy change (Shanahan, Jones, and McBeth 2011, 548). However, similar to the ACF, the PNF suggests a unidirectional view on the relation between policy and expertise as policy narratives are to “strategically deploy scientific information in the pursuit of policy positions” (Shanahan, Jones, and McBeth 2011, 540). Hence the PNF does directly address the role of expertise in the policy subsystem but it does not look at its production. Rather, it suggests that expertise is produced outside of the policy subsystem and then later on fed into the political debate as scientific information.

This unidirectional view on the relation between policy and expertise of the PNF is problematic and raises several questions. If for instance policy-makers are to strategically deploy expertise as suggested by the PNF then the question is in how far this strategic deployment can strengthen the establishment of certain information as expertise while weakening the position of other information. In a similar vein, one might ask in how far policy preferences might trigger the development of expertise that supports specific political objectives. These questions illustrate the mutual impact that policy and expertise can have on each other. The main point is that policy and expertise are not only produced simultaneously and in parallel but also together so that understanding one of them requires understanding the other as well. Therefore, an integration of the production of expertise into an existing meso-level public policy approach would increase its explanatory value.

*Discourse Coalitions*

The figure below illustrates the Discourse Coalitions Approach as developed by Maarten Hajer.

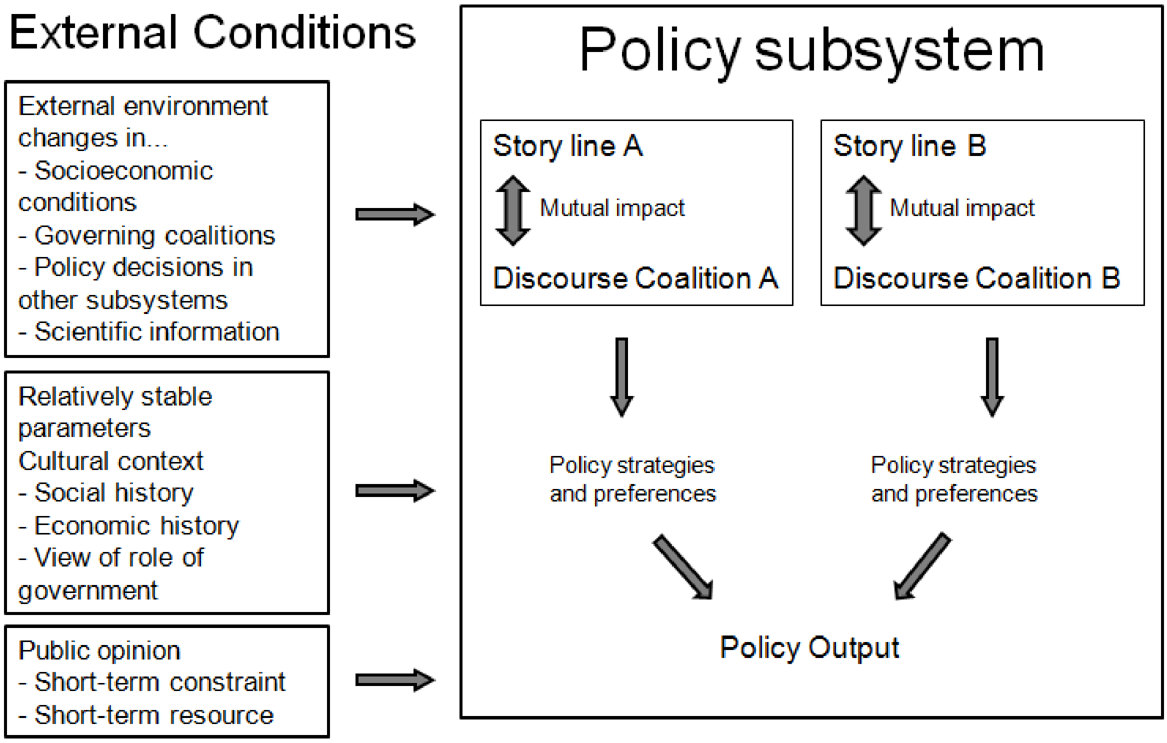



**Figure 4**, The Discourse Coalition Approach

Source: (author's own illustration, adapted from Hajer 1997; Shanahan, Jones, and McBeth 2011, 543)

Hajer (1997) also emphasizes the constructivist dimension of policy subsystems but in contrast to Sabatier and Weible (2007) and Shanahan et al. (2011), he rejects the element of policy beliefs. His critique was well summed up by Frank Fischer who states that the Advocacy Coalitions Framework does not distinguish sufficiently among the diverse actors subsumed in a coalition. While some members of a coalition might be reformers that are willing to negotiate, others might form a fundamental opposition. The tension that arises between both sides can have an important impact on the overall strategy of the coalition and of political leaders (Fischer 2003, 10). Therefore, it is assumed that coalitions are held together by story lines that ascribe meaning to certain events and actions in concrete social contexts (Fischer 2003, 11). Hence it is not pre-existing beliefs that lead to coalition formation but rather storylines that provide a common frame of reference to interpret the reality (Fischer 2003, 13, 15). Furthermore, it is noteworthy that Hajer's concept of discourse coalitions is broader than that of advocacy coalitions as it does not presume that the members of a coalition actually meet and coordinate their activities but rather that coordination occurs in a more indirect way as their activities are derived from a common frame of reference which is in turn reproduced by these actions (Fischer 2003, 15, 16).

This conception, however, has not gone uncontested. Joseph Szarka for instance argues that Hajer waters down the notion of a coalition by rejecting its main idea of concerted action (Szarka 2004, 319). Szarka acknowledges that widening the concept of coalitions helps in analyzing "cases of objective alliances or strange bedfellows" (Szarka 2004, 319). A prime example of objective alliances which presumably do not rest upon shared beliefs or concerted actions can often be found in the field of immigration policy. While conservative parties and labour unions most often form part of opposing coalitions, there are instances of both arguing against the access of foreign workers to the national labour market. Therefore, Szarka suggests applying discourse coalitions to broader alliances, while keeping advocacy coalitions as a narrower sub-set that requires concerted action: "Sabatier's ACF is most applicable when organizations take action in concert, but Hajer's 'discourse coalitions' concept has hermeneutic value when actors sing in chorus – but not necessarily in the same choir" (Szarka 2004, 319).

This brief of Fischer's and Szarka's reflections already clarified that discourse, story line, and discourse coalitions are three central notions in Hajer's constructivist approach. Hajer defines discourse as "a specific ensemble of ideas, concepts and categorizations that are produced, reproduced and transformed in a particular set of practices and through which meaning is given to physical and social realities" (Hajer 1997, 44). Discourses are structured by story lines which Hajer defines as "a generative sort of narrative that allows actors to draw upon various discursive categories to give meaning to specific physical or social phenomena" (Hajer 1997, 56). Hence story lines constitute specific narratives in which diverse components of a discourse are linked to each other in a coherent manner so that they provide orientation and meaning to diverse actors. Similar to Shanahan et al., Hajer emphasizes that these narratives ascribe diverse roles to actors such as victims, problem solvers, perpetrators, top scientists or scaremongers. Furthermore, they ascribe certain attributes to actors and issues such as blame, responsibility, urgency and responsible behavior (Hajer 1997, 64, 65).

The third key notion of Hajer's approach is that of discourse coalitions which "are defined as the ensemble of (1) a set of story-lines; (2) the actors who utter these story-lines; and (3) the practices in which this discursive activity is based" (Hajer 1997, 65). Discourse coalitions support diverse story lines which compete with each other in the overall discourse for acceptance in order to make specific policy options look more suitable and desirable than others. Thus story lines bridge the gap between the discourse coalitions on the actor level and the overall discourse on the context level in Hajer's approach. This means that both practices and context matter as the institutional context enables and constrains opportunities for action and as these actions in turn reproduce or alter the institutional context (Hajer 1997, 48, 59–64). Hence story lines do not determine a coalition's preferences but can also be altered by new information and actors making new experiences.

The role of expertise in Hajer's Discourse Coalitions approach is an ambiguous one. To get to grips with it one needs to look at the broader foundations of Hajer's approach. Hajer assumes that it is impossible for any individual human being to conceive of the complex reality as a whole. Rather, he argues that we all act upon our images of the reality (Hajer 1997, 16). Thus public problems do not reflect an objective reality but are socially constructed in a way that allows policy-makers to deal with them by very concrete solutions (Hajer 1997, 264, 268, 270). Story lines are an important part of this construction as they "fulfil an essential role in the clustering of knowledge, the positioning of actors, and, ultimately, in the creation of coalitions amongst the actors of a given domain" (Hajer 1997, 63). Furthermore, they determine what knowledge is held apart from the discussion and what has become a black box in the sense that it does not have to be considered anymore (Hajer 1997, 272).

Hence expertise is only indirectly included in Hajer's approach in the form of knowledge that is either integrated into specific story lines or discarded. This suggests that Hajer (1997) has a similar view on the relation between policy and expertise as Sabatier & Weible (2007) and Shanahan et al. (2011). Expertise is assumed to be produced somewhere outside of the policy subsystem and fed into the political discussion later on. However, in Hajer's case this view is somewhat surprising as he applies a very constructivist approach suggesting that both policy problems and solutions are socially constructed. Therefore, one might wonder whether expertise in the form of knowledge is not co-constructed with the policy problem and its solution.

In fact, Hajer's approach already hints at the potential mutual impact of policy and expertise on each other as it implies that both the integration and the exclusion of new knowledge can be supported deliberately and strategically by specific actors or take place more indirectly depending on the knowledge's suitability with the dominant story line. However, Hajer's approach focuses only at the analysis of the policy discourse while a co-productionary framework would take the discourse on expertise into account as well. This would supplement the Discourse Coalition approach and increase its explanatory value through the integration of another variable into the investigation. A study that highlights the co-production of policy and expertise might more elaborately explain the construction of public problems and solutions and thus the overall development of public policy.

*Policy entrepreneurs*

The notion of the policy entrepreneur has been deployed by many different scholars in the public policy literature and the wider field of political science in general. Most authors apply the notion in a relatively coherent manner in which policy entrepreneurs are described as individuals who promote certain policy ideas or proposals on the basis of personal interests, values or the simple pleasure from participating in the policy process and being near the power. Hence the main objective of policy entrepreneurs is to set their preferred proposal on the political agenda. For this purpose, they can apply a variety of different strategies. Huitema and Meijerink (2010) have summed up the scholarly literature on policy entrepreneurs and identified five distinct strategies: 1) The development of new ideas, 2) The building of coalitions and selling of ideas, 3) The recognition and exploitation of windows of opportunity, 4) The recognition, exploitation, creation and/or manipulation of the multiple venues in modern societies, 5) The orchestration and management of networks (Huitema and Meijerink 2010, 4-6).

Which of these strategies is/are applied by policy entrepreneurs in a specific case depends on the position of the policy entrepreneur in the political system and on what strategy is regarded as most effective for promoting the desired political objectives (Huitema and Meijerink 2010, 4; Mintrom 1997, 739, 740). Indeed, policy entrepreneurs can hold various positions in the political system. They can for instance come from think tanks, private enterprises, grassroots groups, or from within public administration itself (Mintrom 1997, 747). The position in the political system of course also determines the resources available to specific policy entrepreneurs. Political leaders may for instance have the support of a political party or a bureaucracy which representatives of NGOs do not have (Huitema and Meijerink 2010, 4). Consequently, policy entrepreneurs with the most resources such as money, time, and access to policy-makers are more likely to be successful in promoting their preferred policy idea than others (Zahariadis 2007, 74, 78).

Thus an analysis of the role of policy entrepreneurs in a specific policy field has to focus on the policy ideas that are being promoted, the strategies that are deployed for this promotion, and the resources that are available to the policy entrepreneur in question. This focus on policy ideas, strategies, and resources also serves as a bridge between the concept of policy entrepreneurs and the broader coalition approaches presented in the preceding subheadings. Indeed, the concept of the policy entrepreneur can be easily integrated into the different approaches of advocacy coalitions, policy narratives, and discourse coalitions. In the case of advocacy coalitions for instance the concept of policy entrepreneurs could be used to highlight the role of very influential individual actors that either act within certain coalitions, mediate between opposing coalitions, or even do both. This illustration already indicates that specific actors who possess the required resources and who are willing to invest these to promote specific issues can play a central role in the policy subsystem as outlined by the ACF.

Policy entrepreneurs could also play a key role in the Discourse Coalitions approach of Maarten Hajer. In contrast to the ACF, integrating the concept of the policy entrepreneur into the Discourse Coalitions approach would focus less on coalition membership and inner-coalition activities and more on story lines and the policy entrepreneurs' efforts in promoting and shaping these. In a Discourse Coalitions approach policy entrepreneurs could be conceived of as the most influential and the most active actors of a specific discourse coalition due to the widened understanding of a coalition. If policy entrepreneurs by definition are actors who promote specific policy ideas with the resources available to them, then they also form part of the wider discourse coalition that supports this idea or story line provided there are further actors supporting that idea or story line, of course. Thus an analysis of the role of policy entrepreneurs in a Discourse Coalitions approach would focus on the influence of specific policy entrepreneurs in shaping a specific story line and in advocating it to other actors to win support for it and to broaden the coalition.

In sum, the preceding paragraphs have shown that the concept of the policy entrepreneur can be integrated into different coalition approaches in a fruitful manner. Integrating the concept of the policy entrepreneur into the Advocacy Coalition Framework or the Discourse Coalitions approach provides in both cases an additional focus on the role of influential individual actors in the overall policy subsystem and thus supplements the general focus on coalitions in a useful way. As pointed out above, however, there are certain differences in the combination of the concept of a policy entrepreneur with the Advocacy Coalition Framework and the Discourse Coalitions approach due to the general differences of these meso-level public policy approaches with regard to their distinct understandings of coalitions and beliefs or story lines. These differences are summed up in the following subheading explaining why the Discourse Coalitions approach of Maarten Hajer is most suitable for the purposes of this thesis.

*Conclusion*

The Discourse Coalitions approach of Hajer will be deployed in combination with the concept of the policy entrepreneur in this thesis for several reasons. First, the discursive and constructivist nature of Hajer's approach suits best to the main objective of this thesis which is to investigate the development of two interrelated discourses. Hajer provides sophisticated tools for the analysis of the policy discourse. This thesis is to supplement his approach by providing equivalent tools for the analysis of the discourse on expertise.

Second, the concept of Discourse Coalitions takes into account that diverse actors do not actually have to meet each other in order to commonly argue for the same policy option. They do not even have to take notice of each other but rather their actions are coordinated through the same story line that serves as a common frame of reference. Hence the Discourse Coalitions approach allows taking influences into account that would fall outside of the analytical framework of the Advocacy Coalition Framework or the Policy Narrative Framework.

Third, the concept of Discourse Coalitions rejects the component of policy beliefs which is not to say that these do not exist. Rather it means that diverse actors can support certain story lines for a variety of reasons which they might never utter in public. Of course, all actors will provide an official explanation for their point of view but their actual intentions might differ and shedding light on them remains problematic and, to some extent, unnecessary.

These illustrations should clarify that the Discourse Coalitions approach offers a variety of advantages with regard to the purposes of this thesis in comparison to the Advocacy Coalition Framework and the Policy Narrative Framework. In addition, integrating the concept of the policy entrepreneur into the Discourse Coalitions approach allows taking the influence of individual actors into account, too. Therefore, a combination of the Discourse Coalitions approach and the concept of the policy entrepreneur constitutes the most promising means for the analysis of the European policy discourse on hydrogen and fuel cell technologies. Furthermore, the concept of the policy entrepreneur allows building a bridge between the analysis of the policy discourse and the expertise discourse as will be outlined in detail in subchapter 3.5 that presents the theoretical framework that will be applied for the analysis of the co-production of EU H & FC policy and expertise in this thesis. First, however, the following subchapter provides a review of the scholarly literature on the provision of expertise outlining the different dimensions of expertise that have to be taken into account in a comprehensive analysis of this issue.

## 3.4 Scholarly literature on the provision of expertise

While the previous subchapter outlined how the policy discourse is to be analysed, this subchapter illustrates how the discourse on expertise will be dealt with in this thesis. For this purpose, it will be drawn upon the rich pool of scholarly literature on the production of expertise for policy-making that has been brought about in the past decades. However, it should be noted that this thesis neither attempts to provide a theoretical contribution to this literature nor that it attempts to summarize this strand of research exhaustively. This thesis primarily contributes to the literature on the governance of EU R&I policy as outlined in chapter 2 and is to use the literature on expertise only to supplement existing public policy approaches. Furthermore, it goes beyond the scope of this thesis to provide an exhaustive summary of the scholarly literature on expertise. Rather, this subchapter will focus on the recurrent themes that could be identified in the scholarly literature on expertise studied. The objective is to purposefully sum up insights from diverse disciplines that contribute to the development of a coherent approach for the analysis of the provision of expertise.

Analogous to Hajer's constructivist approach for the analysis of the policy discourse, this thesis applies a social constructivist point of view on the development of science and expertise. The implications of this are well summed up by Sheila Jasanoff from the field of Science and Technology Studies: "We regard a particular factual claim as true not because it accurately reflects what is out there in nature, but because it has been certified as true by those who are considered competent to pass upon the truth and falsity of that kind of claim" (Jasanoff 1994, 12, 13). This perspective is shared by other scholars related to Science and Technology Studies. Yaron Ezrahi for instance describes science as a cultural enterprise such as religion or art in the sense that it constitutes a distinct cluster of forms of authority, discourse, and action (Ezrahi 1990, 9). Ludwig Fleck emphasizes that the production of knowledge is a deeply social activity as new knowledge always stems from a community of persons that shares a particular way of thinking rather than from individual efforts (Fleck 1981, 39). Also Jerome Ravetz, a philosopher of science, points in the same direction and argues that scientific facts are not established as much by correct and objective scientific inquiry as by the recognition of the results of the inquiry by the specific community in the research area in question (Ravetz 1971, 184, 185).

Thus the aim of this thesis is to highlight the process of the constitution of expertise and not to judge the quality of expertise or to elaborate in how far the expertise constituted depicts the reality. For this purpose, the following paragraphs present a selective overview of the scientific literature on the provision of expertise including findings from authors that do not share a social constructivist perspective. The scholarly literature on the provision of expertise highlights above all with three key issues: 1) Venue and mode of production, 2) The selection of experts, and 3) Effects and usage. These three issues should not be perceived as independent of each other but rather as partly overlapping categories as will be outlined in the following paragraphs. In addition to these three issues, the demarcation between expertise and science is of utmost importance which is why it constitutes a recurrent theme throughout all of the three subheadings. Finally, the main insights gained from the scholarly literature are summed up under the fourth subheading "Dimensions of expertise" highlighting the different aspects that are to be included in the analysis of the provision of expertise in this thesis.

*Venue and mode of production*

The following paragraphs sum up the findings of studies that have highlighted the venue and the way of production of expertise. First, however, it must be emphasized that it is without controversy that scientific knowledge and expertise are produced in differing settings and in diverse ways. Fuller, for instance, states that science evokes a universalistic ideal meant to be pursued in leisure, while expertise refers to particular practices pursued to earn a living (Fuller 2008, 115). Stehr and Grundmann, two sociologists of science, argue that expertise is not provided by professions or science in general but rather by individual actors (Stehr and Grundmann 2010, 109). The reason for this lies in the very nature of expertise as there are no standards for its production but rather appropriate methods have to be negotiated during the process of the making of expertise (Weingart and Lentsch 2008, 21). Indeed, also Sheila Jasanoff from the field of Science and Technology Studies argues that the production of expertise differs fundamentally from conventional scientific research as the credibility of expertise “ultimately rests upon factors that have more to do with accountability in terms of democratic politics, than with the quality of science as assessed by scientific peers” (Jasanoff 2003, 233). Thus, in contrast to conventional scientific research, the production of expertise depends less on scientific communities in specific disciplines and more on the interaction between scientists or experts and policy-makers or the broader public.

Jasanoff (1994) highlights these relations between scientists and policy-makers further in another study of the relationship between regulatory agencies and scientific advisers in the USA using the examples of the Environmental Protection Agency and the Food and Drug Administration and their advisory committees. Above all Jasanoff emphasizes the importance of boundary work between science and policy-making for the provision of expertise in order to prevent the impression that policy-makers select the expertise that suits their pre-defined objectives and to guard policy-makers against being dragged into scientific debates. Both the Environmental Protection Agency and the Food and Drug Administration gained advice from and were accountable to several ad hoc and standing expert committees and for both agencies it was of great importance to contact external experts not only in good time but also to maintain collegial relations with them (Jasanoff 1994, 229). Thus expertise cannot be conceived of as something created by scientists and received by policy-makers but rather as something produced in the interaction of scientists and policy-makers and affected by both.

Also the two sociologists of science, Weingart & Lentsch, underline that scientific political consulting is broader than scientific knowledge and also includes bureaucratic, technical and practical knowledge about target groups or organizational processes (Weingart and Lentsch 2008, 20, 21). The key difference is that scientific knowledge has to be epistemically robust while scientific political consulting needs to be socially robust (Weingart and Lentsch 2008, 22).[3] This means that scientific knowledge needs to be acknowledged by the scientific community whereas scientific political consulting needs to be politically acceptable and feasible and has to be adjusted to values and interests (Weingart and Lentsch 2008, 50, 51). Hence scientific political consulting presumes that scientific knowledge is selected according to its relevance for a specific problem and interpreted and assessed in a certain way (Weingart and Lentsch 2008, 46).

According to Weingart & Lentsch the production of expertise includes several types of activities such as research-based production of knowledge for the clarification of the features of the problem, gathering and search of knowledge as well as the production of predictive expertise in form of predictions or scenarios (Weingart and Lentsch 2008, 46, 47). In the authors' view the production of expertise resembles what Nowotny et al. and Gibbons et al. have labelled as "mode2" (Gibbons et al. 1994; Nowotny, Scott, and Gibbons 2001). Thus expertise is generated in new venues such as think tanks or private enterprises; it is

3 Although it should be noted that there is a certain number of reputational authors from research fields such as the Sociology of Science and Science and Technology Studies who argue that also the production of scientific knowledge should aim at social robustness. See for example Funtowicz and Ravetz 1993 or Nowotny, Scott, and Gibbons 2001

problem-oriented, project-based and transdisciplinary; it pays great attention to the treatment of risks or non-knowledge; and its quality is not ensured by scientific standards alone but also by economic and political criteria, as it is characterized by an increased accountability to the public and civil society (Weingart and Lentsch 2008, 19, 20).

In his attempt to categorize all these diverse sorts of expertise, Buchholz, who also belongs to the field of the sociology of science, suggests distinguishing among four types of expertise according to the relationship between experts and policy-makers. (1) Expertise can be provided in a very informal way as for example in conversations between two persons at dinner. In this case expertise comes along in the form of verbal communication. (2) Another but more formal example of expertise in the form of verbal communication is characterized by official hearings hold at parliaments, ministries, etc. (3) Expert reports conducted on the behalf of government authorities constitute a written form of expertise. (4) Finally, there is expertise in the form of institutionalized and regular verbal communication as for example in committees, advisory boards, etc. (Buchholz 2008, 88).

Weingart & Lentsch have found six institutional settings in their study of scientific political consulting in Germany: (1) scientific advisory boards of government departments, (2) scientific expert committees in risk and safety management, (3) advisory councils in specific policy fields, (4) ad hoc committees, (5) committees of inquiry, and (6) research units of government departments (Weingart and Lentsch 2008, 53, 54). The authors argue further that in all six settings, the relationship between experts and policy-makers has an impact on the content of expertise. The more independent experts are from their principal, the more will they be able to provide epistemically robust expertise, conversely experts that are more dependent on their principal are more likely to provide politically robust expertise (Weingart and Lentsch 2008, 54, 55). Based on their findings, Weingart & Lentsch suggest distinguishing committees on the following criteria: a) expected/supposed function in the political process, b) type of institutionalization and rules of constitution, c) procedures of recruitment and selection, d) institutional relation to the client or contracting authority, e) way of work (degree of epistemic robustness, procedures of voting in case of conflict etc.), f) usage and form of results (publications, reports and what is the client supposed to do with them) (Weingart and Lentsch 2008, 55, 56).

In summary, these illustrations show that one should focus on the criteria that matter in the process of making expertise, on the setting and the degree of institutionalization and on the relationship between experts and policy-makers as all of these affect the production of expertise. However, relationships among experts and policy-makers should not be treated as given but rather it should be problematized how certain persons gain the status of an expert while others do not.

*The selection of experts*

Diverse authors have elaborated how certain individuals gain the status of an expert on specific issues and in specific settings. Stehr and Grundmann for instance have a look into diverse understandings of the notion of an expert in among others the English Encyclopedia Britannica and Brockhaus, the largest German language encyclopaedia (Stehr and Grundmann 2010, 16, 17). In the end, they define experts as persons who gained experience by regularly dealing with specific issues and hence have a good reputation and enjoy public confidence (Stehr and Grundmann 2010, 9).Furthermore, experts are persons who deal with the transfer and utilization of knowledge (Stehr and Grundmann 2010, 20).

Weingart & Lentsch derive their definition of experts from the assumptions on functional differentiation between politics and science of Luhmann’s system theory. In their view, experts are defined as persons who possess the scientific knowledge required for the solution or analysis of the problem in question and who are employed at an institution which is dedicated to the criteria of truth in the production and communication of knowledge. Hence experts can also come from private think tanks, research institutes or research units of private enterprises but not from interests associations. A person’s primary reference to either science and truth or politics and power decides whether he or she can be conceived of as an expert (Weingart and Lentsch 2008, 47).

In contrast to these comparably clear-cut definitions, other authors emphasize that the ascription of the status of an expert heavily depends on the context. McKechnie (1996) for instance found in an empirical study on the Isle of Man that scientific authority, for example in the form of acquired academic titles, does not have to be valued in local contexts. Rather, the status of an expert can be ascribed in local contexts due to many other issues than scientific knowledge such as established local status, personal experience, general and local knowledge, intelligence, presentational skills and competence in day-to-day life (McKechnie 1996, 131–133).

Stephen Hilgartner (2000) points in the same direction. He sheds light on how scientific authority is constituted by examining the controversies that emerged out of three scientific reports on diet and health produced by committees of the American National Academy of Science in the USA. One of Hilgartner's main points is that there is strict separation between the so-called front stage and the back stage. While the front stage denotes the scientific reports as published in their final versions, the back stage refers to how these reports were compiled in fact. In Hilgartner's view the front stage always displays unity among the compositors of a scientific report, emphasizes their institutional affiliation, tries to tie as many well-respected scientific institutions to the report as possible (reviewers, committee of experts, and so on), and presents a consistent narrative so that the reader of the scientific report does not get to know all the disagreements, the diverging opinions, and the disputes and negotiations that often characterize the compilation of scientific reports on the back stage. Hence information control and the strict social, spatial, and temporal separation of front stage and back stage is used to create unquestionable scientific authority (Hilgartner 2000, 43-54).

As a consequence, Hilgartner recommends analyzing how scientific authority is established through highlighting the processes that take place on the back stage. Above all Hilgartner suggests that studies of the provision of expertise should focus on bringing disagreements on the back stage to light and on illustrating how the authors of scientific reports were selected. As these reports are usually prepared by committees composed of representatives from various organizations Hilgartner recommends asking for the rules of committee selection in order to determine how, why and by whom the experts that compiled the reports were selected (Hilgartner 2000, 54–70).

Indeed, Sheila Jasanoff from the field of Science and Technology Studies points in the same direction. According to Jasanoff, incoherence instead of consensus is the prevailing condition in many research areas that produce policy-relevant knowledge. Thus scientists can no longer provide advice that is derived from scientific knowledge that is undisputed among the scientific community. Rather, “what politicians and society increasingly expect from experts in decision-making processes is the ability to size up heterogeneous bodies of knowledge and to offer balanced opinions, based on less than perfect understanding, on issues that lie within nobody’s precise disciplinary competence” (Jasanoff 2005, 211).

This thesis is to follow the approach of McKechnie (1996) and Hilgartner (2000) in the respect that it is not defined *a priori* what characterizes an expert but rather that it is the aim of the study to find out the reasons that led to the selection of certain persons as experts while others have been disregarded. The primary questions appear to be: Who is selected to serve as an expert? Why was this specific person chosen? How did the selection take place? These questions of course relate to the venue and the mode of production of expertise. It could for instance be assumed that the procedure of selection gains importance with a higher degree of institutionalization of the provision of expertise as government officials need to legitimize their choice of experts for certain committees. Yet, how this procedure takes place and whether scientific, political or any other criteria prevail remains an empirical question that is to be addressed in this thesis.

*Effects and usage*

Finally, it has to be distinguished among the diverse roles that expertise can play in public policy. This means above all to identify how expertise is used by policy-makers and what effects it has on the further course of the public policy process. McKechnie found that scientists or experts that are brought into a local context often have to sort of translate their scientific expertise for their audience (McKechnie 1996, 141–143). Buchholz points in the same direction and underlines that the difference between abstract, scientific knowledge and its application to the case in question constitutes the major problem that has to be overcome in the provision of expertise because good expertise not only has to be based on scientific knowledge but also has to provide the recipient with opportunities for action (Buchholz 2008, 211).

However, the assessment of the usability of the expertise provided depends highly on the institutional context in which it takes place as Kropp argues (Kropp 2012, 229). Also Stehr and Grundmann emphasize the view of the recipients of expertise. They distinguish among four roles that experts can have in the provision of expertise. (1) Experts have to mediate among the production and the use of knowledge that is to say among those that create opportunities for action and those that have to act. (2) Experts need to reduce complexity and to build trust. They have to select the relevant information from all the available information and to present clear and convincing conclusions and recommendations. (3) Experts can also have a legitimating role as policy-makers are interested in credible and reputed experts and expertise. (4) Finally, experts have to define situations and opportunities as well as priorities for action (Stehr and Grundmann 2010, 43–51).

Hence expertise can not only outline specific opportunities for action to policy-makers but also legitimize these. Yet, policy-makers decide by themselves whether and how they make use of the expertise provided to them by experts. Weible, a political scientist, distinguishes among three types in which policy-makers can make use of expertise: instrumental, learning, and political.  Instrumental means that expertise directly impacts policy that is to say policy-makers listen to their experts and apply the expertise provided in a rational and practical manner to solve problems. In contrast, learning means that expertise can indirectly affect policy-making by fostering learning, belief change and policy change. Finally, a political use of expertise is characterized by policy-makers that only make use of the expertise provided if it suits their *a priori* defined objectives. In this case, they employ the expertise to argue against opponents. However, if the expertise does not comply with their predefined objectives, policy-makers just ignore it (Weible 2008, 615).

Weingart and Lentsch draw similar conclusions. They analyse the relationship between policy-makers and experts from the viewpoint of Luhmann's system theory according to which policy-makers and scientists have diverging interests on the use of expertise. Both sides seek to control knowledge communication, interpretation and diffusion. Therefore, the potential impact of expertise depends among others on what authority experts have in policy-making and in what areas do they have a say (Weingart and Lentsch 2008, 27, 28). Policy-makers seek political power while scientists pursue profession-related interests (Weingart and Lentsch 2008, 207). Hence the provision of expertise can be either science- or policy-dominated. While the former does not have a political impact or only serves for the critique of certain decisions, the latter constitutes a political use of expertise for the ex-post legitimization of decisions (Weingart and Lentsch 2008, 53, 54).

In their study of scientific political consulting in Germany Weingart and Lentsch identified two main functions that expertise can fulfil in the policy-making process, both of which are reminiscent of Weible's distinction between an instrumental and a political use of expertise. Weingart and Lentsch speak of problem-oriented functions and political functions. Problem-oriented functions include precaution, problem analysis, identification and assessment of potential political actions, formulation of recommendations, development of standards, evaluation of proposals etc., while political functions refer to consent building in times of diverging interests, informing the broader public or specific stakeholders, legitimization and evaluation of political measures and programmes (Weingart and Lentsch 2008, 28, 29). Yet, Weingart and Lentsch do not share Weible's last point and argue that policy-makers cannot ignore scientific knowledge in the long run and particularly not in modern democracies with mass media (Weingart and Lentsch 2008, 17). However, they admit that a direct impact of expertise on policy-making, as for example in a rationalization of public policy, is rather rare as expertise is used according to the logics of public policy (Weingart and Lentsch 2008, 32).

These illustrations should clarify that one has to take into account both the purposive use of expertise by policy-makers and its implications and the indirect effects that generated and communicated expertise can have.

*Dimensions of expertise*

This subheading is to summarize the main insights gained from the review of the scholarly literature in the preceding three subheadings in order to illustrate the different dimensions of expertise that will be included in the analysis of the co-production of EU H & FC policy and expertise in this thesis. The review of the scholarly literature has shown that there is no uniform conception of expertise so that different authors shed light on different aspects and use different notions to describe the provision of expertise. While for instance Jasanoff (2005) speaks of policy relevant knowledge, Weingart & Lentsch (2008) and Buchholz (2008) deploy the term scientific political consulting ("wissenschaftliche Politikberatung"). In contrast to these notional differences, however, all studies reviewed highlight similar dimensions in the provision of expertise such as effects and usage, venue and mode of production, the selection of experts, and the establishment of specific information as expertise. These dimensions are briefly summarized in the following paragraphs in order to illustrate the different issues that a comprehensive analysis of the provision of expertise has to focus on.

First, any analysis of expertise has to highlight what knowledge eventually was established as expertise and what knowledge was discarded as Hilgartner (2000) explained with his distinction between the front stage and the back stage in the compilation of expert reports. Furthermore, several authors such as Jasanoff (2005) and Weingart & Lentsch (2008) pointed out rightly that the knowledge used in the provision of expertise systematically differs from scientific knowledge. For the purpose of conceptualizing this specific sort of knowledge used in the provision of expertise, it appears to be useful to deploy Helmut Willke's distinction among three components of knowledge. First, data is a sort of raw material of knowledge that is encoded in numbers, language, texts or images. Second, information is data that was put in a basic context of relevance. Third, knowledge constitutes the embedding of information in a practical context (Willke 2004, 17, 18). Hence the knowledge part of expertise might be conceived of as information that is put in a very specific context which can either be the context of a scientific discipline or the context of a practical problem. Of course, it makes a huge difference whether expertise highlights the risks of a specific issue for public health or whether it puts emphasis on the promising economic prospects of this issue. Thus what context dominates is of great importance for the production of expertise but remains an empirical question that has to be answered separately for each case in which expertise is provided.

Second, it has to be clarified where, how, and by whom the expertise in question was produced. These questions refer to the selection of experts as well as to the venue and the mode of production of expertise. An analysis of the provision of expertise not only has to answer who was selected to serve as an expert but also why this specific person was chosen and how the selection took place. Of course, these issues on the selection of experts also relate to the venue and the mode of production of expertise. Was expertise provided in an institutionalized setting through an advisory committee whose members were selected in a formalized procedure and instructed to compile an expert report on a specific issue? Or was expertise provided through informal talks between policy-makers and specific individuals who were personally perceived as authorities on a particular issue by the policy-makers in question? These questions should not be thought of as predefined categories but rather as illustrations of the different dimensions and issues that a comprehensive analysis of the provision of expertise has to focus on.

Third, various authors have emphasized the different effects that the provision of expertise can have as well as the different ways in which specific expertise can be used by certain actors. Experts can for instance show up new opportunities for action or legitimate certain actions through the provision of specific expertise. Policy-makers can opt for directly applying the expertise provided in order to solve specific problems in a practical manner or they can choose to only apply the expertise provided if it supports their *a priori* defined objectives. Whether or not policy-makers can ignore specific expertise on a sensitive issue in the longer run depends on many factors. It is for instance easily conceivable that specific expertise illustrating the risks of new technologies to public health might prove difficult to ignore once these information have reached public media, NGOs, and the broader public.

Finally, the different dimensions of expertise outlined in the preceding paragraphs already indicate potential imbalances in the co-production of policy and expertise. Experts could for instance have their own political objectives and provide very specific expertise that supports these. Likewise, policy-makers could only select those experts for advisory committees that they expect to provide the expertise needed to support *a priori* defined political objectives. These examples indicate that the relation between policy and expertise does not have to be a symmetrical one but that the logics of the policy process could dominate the production of expertise and *vice versa*. Whether and if so what side was more influential in the case of EU H & FC policy and expertise is an empirical question that will be answered in detail in the chapters 6-9. First, however, the following subchapter illustrates the conceptual framework for the analysis of the co-production of policy and expertise that was developed on the basis of the public policy approaches outlined in preceding subchapter and the scholarly literature on the provision of expertise that was discussed in this subchapter.

## 3.5 A co-productionary framework

This subchapter outlines the theoretical framework that is to be applied for the analysis of the co-production of EU H & FC policy and expertise in this thesis. For this purpose, it is split into two subheadings. First, the idea of two parallel and interrelated discourses on policy and expertise is illustrated in more detail. This means, above all, an explanation is presented as to how the discourse on expertise is integrated into the meso-level public policy approach of Discourse Coalitions. Second, the implications of this integration are outlined, and it is shown how the co-production of policy and expertise can be analyzed in practice.

*Integrating the discourse on expertise into the policy subsystem*

The idea of two different but interrelated discourses on policy and expertise is not new but has been put forward by diverse public policy scholars. Peter Haas for instance has introduced the notion of an epistemic community as “a network of professionals with recognized expertise and competence in a particular domain or issue-area” (Haas 1992, 3). Haas speaks of four factors that hold an epistemic community together: 1) a shared set of normative and principled beliefs, 2) shared causal beliefs, 3) shared notions of validity, and 4) a common policy enterprise (Haas 1992, 3). The political relevance and power of epistemic communities stems from their authoritative claim to provide expertise on a specific policy issue (Haas 1992, 16). Epistemic communities can influence policy-making through highlighting cause-and-effect relationships and through illustrating the likely results of specific policy actions (Haas 1992, 15). Although Peter Haas has developed the notion of epistemic communities to investigate the influence of expert communities on international policy coordination, his work clearly reflects the idea of two separate but related discourses on policy and expertise.

Vivien Schmidt (2007) distinguishes between a communicative and a coordinative discursive sphere. While policy actors generate new ideas in the coordinative sphere, they present these ideas to the broader public for deliberation in the communicative sphere (Schmidt 2007, 993). Amandine Crespy (2010) applies a similar distinction between the communicative and the coordinative discourse: “On the one hand, discourse between the political elites and the wider public within the political sphere is defined as communicative discourse: it is used in politics and is grounded in normative ideas and appeals to values. On the other hand, coordinative discourse defines the discursive interactions between policy actors within 'epistemic communities' and relies mainly on cognitive ideas and scientific rationality" (Crespy 2010, 1258).

The distinction between a policy discourse and an expertise discourse in this thesis comes close to Crespy's distinction between a communicative and a coordinative discourse. While the policy discourse is led by discourse coalitions that support competing story lines, the expertise discourse is characterized by all the different dimensions of expertise explained in subchapter 3.4. Both are part of one and the same policy subsystem as illustrated by the figure below.

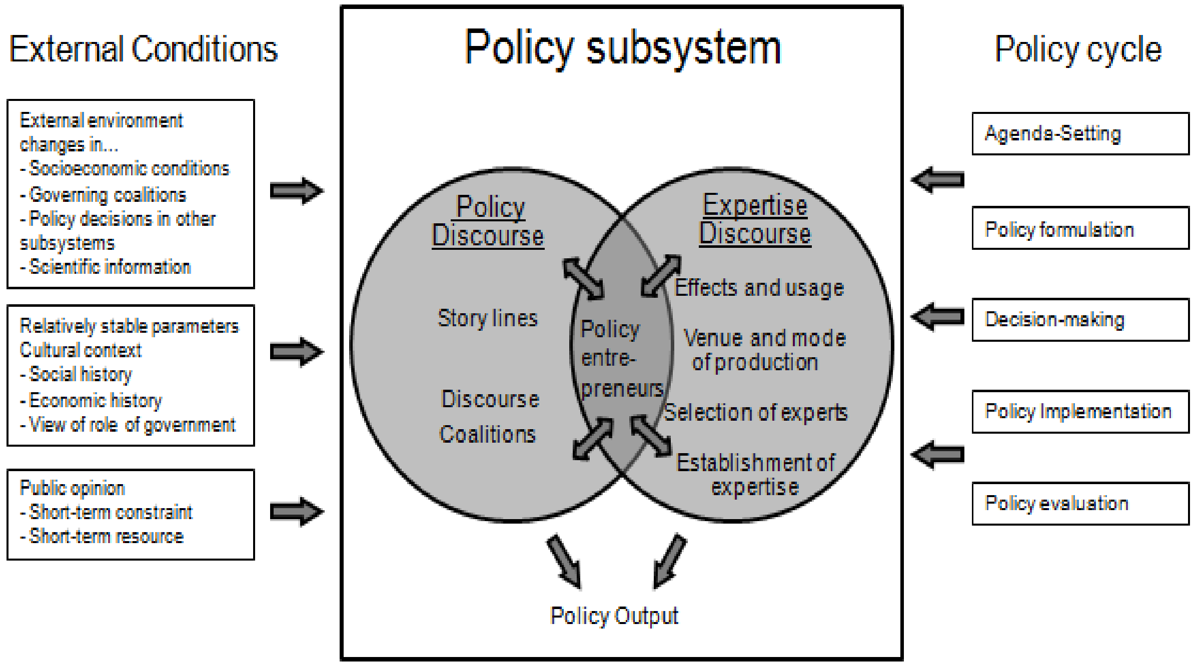



**Figure 5**, The discourses on policy and expertise integrated into the policy subsystem

Source: (author's own illustration, adapted from Shanahan, Jones, and McBeth 2011, 543)

The figure is to visualize how the discourse on expertise is integrated into the meso-level public policy approach of Discourse Coalitions in this thesis. It is this integration that distinguishes the theoretical framework of this thesis from the public policy approaches outlined in subchapter 3.3. The external conditions that affect the development of the policy subsystem remain the same including external scientific information that are of importance in the policy subsystem in question but that were produced outside of it such as, for example, studies on climate change, forecasts on global energy demand, etc. The innovation lies in the integration of the discourse on expertise as an internal element into the policy subsystem. The reason for this is that the two separate but interdependent discourses on policy and expertise are part of the same policy subsystem. Therefore, the interplay between the policy discourse and the expertise discourse determines the further course of the policy subsystem. In other words, the co-production of policy and expertise results in the policy output.

Furthermore, the right side of figure 5 displays the different stages of the policy cycle model that is to be used as a structuring device for the empirical chapters of the thesis. This means that the co-production of policy and expertise will be analyzed for all different stages of the policy process. These stages, however, do not have to directly correspond to the five stages of the policy cycle model. As already pointed out in the explanation of the policy cycle model in subchapter 3.2, there is no clear-cut separation between the different stages but rather the specific dynamics of each stage can be present at any time in the policy process. Consequently, the five stages outlined above will not be imposed *ex ante* on the empirical data in this thesis but rather the empirical chapters will be structured according the specific dynamics that characterized certain periods in time according to the empirical data. Thus it remains an empirical question whether for instance the years of 2000-2003 most resembled the dynamics of the stage of agenda-setting or whether it makes more sense to categorize the years of 2000-2004 as one period in which the dynamics of agenda-setting and decision-making were the most prevalent ones according to the empirical data. Hence the structuring of the empirical chapters will be firmly grounded on the basis of the empirical data and any categorization into different policy stages at different periods in time will be performed with the main objective to clearly point out the most prevalent dynamics at that period in time.

Finally, it should also be noted that the co-productionary framework depicted in figure 5 does not presume that policy and expertise rest on equal footing. While the main objective of this thesis is to investigate the simultaneous and interrelated production of EU H & FC policy and expertise in the years of 2000-2014, this does not mean that either the production of policy or that of expertise cannot be more important than that of the respective other at different periods in time or even throughout the entire time period that is analyzed in this thesis. Hence it remains an empirical question whether policy and expertise function on equal footing in the co-production of EU H & FC policy and expertise in the years of 2000-2014 or whether one of them is more dominant than the other in some periods of time or throughout the entire period of investigation.

These illustrations should further clarify the general features of the analytical framework outlined in figure 5. On this basis, the following subheading will explain how this analytical framework is to be applied in more detail focusing on the heart of the model which is the interface between the two discourses on policy and expertise.

*Analyzing the co-production of policy and expertise*

The key means in the analysis of the co-production of policy and expertise is the concept of the policy entrepreneur. In fact, the main assumption of the analytical framework depicted in figure 5 is that the co-production of policy and expertise is mainly the result of the interaction of different actors operating at the interface between the two discourses and linking the different components to each other. These actors can for instance be officials of the EC, scientists from public research institutes and universities, or representatives of private enterprises and non-governmental organizations. All of these different actors are involved in the co-production of policy and expertise albeit to varying degrees depending, among others, on the resources available to them. Therefore, the concept of the policy entrepreneur will be applied in this thesis in order to further analyse the interaction between these actors and to highlight what actors are most influential in the co-production of policy and expertise.

Hence the use of the concept of the policy entrepreneur in this thesis is mostly in line with the usual use of the notion in the scholarly literature. The main difference is that this thesis has a slightly stronger emphasis on where the information provided by the policy entrepreneur actually comes from. That is to say, in addition to the usual analysis of the impact of the policy entrepreneur in the policy discourse, this thesis also highlights his or her role in the discourse on expertise. Hence this thesis not only looks at what specific proposals policy entrepreneurs advocate but also at what information they provide, what information they discard, and on what this means for the establishment of expertise. Thus the usual understanding of the notion of the policy entrepreneur in the scholarly literature is not adapted but rather supplemented by a complementary focus on the discourse of expertise.

In sum, the concept of the policy entrepreneur is to be used to highlight what actors dominate the co-production of policy and expertise. More specifically it will be used to analyze how certain actors link the different components of the two discourses to each other and how they promote this view to a wider range of actors. Hence an analysis of the co-production of policy and expertise requires investigating the relation between the main elements of both discourses. For this purpose, the concept of the policy entrepreneur will be applied as illustrated in the table below.

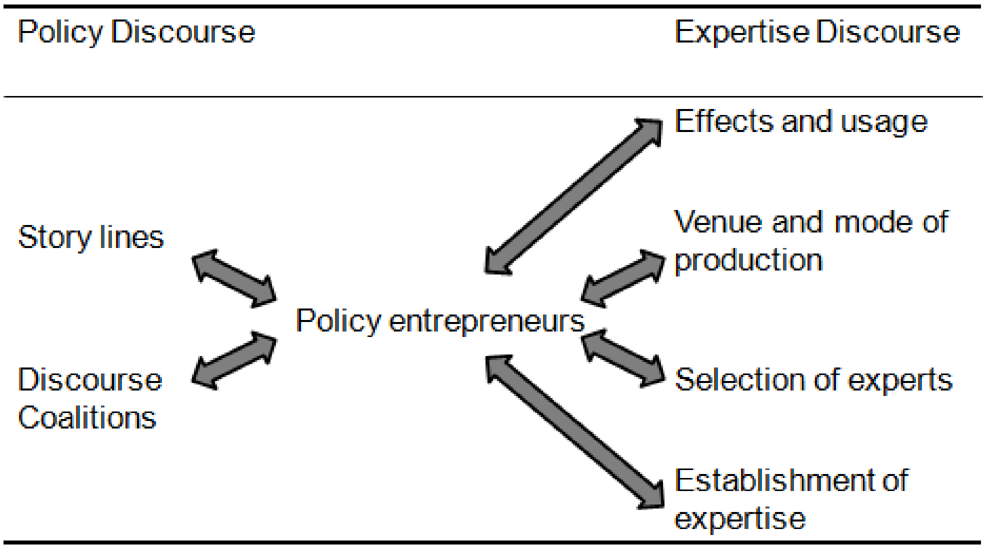



**Table 1**, Policy entrepreneurs linking the different components of the two discourses to each other

Source: (author's own illustration)

As table 1 depicts, the concept of the policy entrepreneur will be used to analyze how specific actors link the story lines and discourse coalitions of the policy discourse to the different dimensions of expertise in the expertise discourse and *vice versa*. Thus the conceptual framework developed takes into account both the meso- and the actor-level and allows analyzing the simultaneous and interrelated production of policy and expertise with a specific focus on the role of individual actors in linking the different components of the two discourses to each other. This indicates a variety of questions that have to be answered in the empirical analysis. These questions not only illustrate the complexity of the co-production of policy and expertise but also point to potential imbalances in simultaneous and interrelated production of policy and expertise as will be outlined in the following paragraph.

One question that has to be answered is for instance how specific policy entrepreneurs link the different components of story lines and the selection of experts to each other. Do certain story lines support the selection of specific experts at the expense of others? Can policy entrepreneurs themselves become experts and this way establish specific expertise that supports their preferred story line? Or can specific experts become policy entrepreneurs and use their expertise to alter dominant story lines and discourse coalitions? All of these questions, of course, also touch upon the effects and the usage of expertise. Do certain policy entrepreneurs only transfer that information from the expertise discourse to the policy discourse that suits the story line that they support? Or can the development of novel expertise bring new policy entrepreneurs onto the stage that challenge dominant story lines and the discourse coalitions that support these? Furthermore, the specific way in which expertise is produced and transferred into the policy discourse has to be clarified. Is expertise transferred via personal relationships in informal settings or via formalized processes with official rules for the selection of experts and the compilation of expert reports?

All of these questions have to be answered in order to shed light on the co-production of EU H & FC policy and expertise in the years of 2000-2014. The key means in this endeavour will be the concept of the policy entrepreneur as has been pointed out in the preceding paragraphs. The following subchapter provides a complete overview of the conceptual framework that has been developed in this chapter for the analysis of the co-production of policy and expertise.

## 3.6 Conclusions

This chapter has introduced the theoretical framework of this thesis. First, different approaches to the idea of co-production have been explained. In this thesis the notion of co-production will be applied to investigate the simultaneous development of policy and expertise in the policy subsystem. For this purpose, different meso-level public policy approaches have been compared with each other with regard to their view on expertise. Eventually, the Discourse Coalitions Approach in combination with the concept of the policy entrepreneur has been chosen as the one most compatible with the constructivist ontology underlying this thesis. Subsequently, the scholarly literature on the provision of expertise has been elaborated highlighting four main issues that any analysis of the provision of expertise has to consider. Finally, both the Discourse Coalitions Approach and the insights from the scholarly literature on expertise were merged into a coherent framework for the analysis of the co-production of policy and expertise. The co-production of policy and expertise takes place at the interface between the two discourses with individual policy entrepreneurs playing a key role in linking the components of the different discourses to each other.

This theoretical framework will be applied to analyze the co-production of policy and expertise in the area of hydrogen and fuel cell technologies in the EU. For this purpose, the following chapter 4 will first provide an in-depth description of the promotion of hydrogen and fuel cell technologies in the EU illustrating the parallel development of policy and expertise in this area. Thereafter, chapter 5 will outline the methodology underlying this thesis and the empirical data collected for the analysis. Subsequently, the results of the analysis and the interpretation of the empirical data will be presented in the chapters 6-9. For this purpose, the policy cycle model will be applied as a heuristic device to point out the specific dynamics of the co-production of EU H & FC policy and expertise at different periods of time.

# 4 The case of Hydrogen and Fuel Cell Technologies

This chapter provides an in-depth description of the empirical case studied in this thesis. While the theoretical framework of this thesis has been outlined in chapter 3 and the empirical data collected as well as the methodology applied for their analysis will be illustrated in chapter 5, this chapter serves as a bridge between both in the sense that it explains the empirical case that is investigated in more detail. The hopes and promises associated with H & FC and the political relevance derived from them have already been indicated in the introduction. However, this chapter will present a more thorough description in order to provide the reader with a better understanding of the empirical analysis that is to follow in the chapters 6-9.

For this purpose, the chapter at hand is split into four subchapters. First, the working principles of H & FC and their potential areas of application such as for instance passenger vehicles, distributed energy systems, and energy storage are illustrated. Thereafter, the volatile history of the development of H & FC including technological breakthroughs and drawbacks is outlined. Third, it will be described in how far the promotion of hydrogen and fuel cells by the EC exemplifies broader trends in EU R&I policy in order to elaborate the representativeness of this empirical case and the limitations of potential generalizations from it. Finally, a brief descriptive summary of the parallel development of EU H & FC policy and expertise in the period of 2000-2014 is provided as this constitutes the empirical case that is investigated in this thesis.

However, before diving into the details, some general clarifications have to be made. The main point is that there is a trade-off between technical or physical accuracy and readability. For instance, it is common to speak of energy consumption although in a strict scientific sense energy cannot be consumed but only converted from one form of energy into another one. In a similar manner it is common to speak of hydrogen production although hydrogen is not actually produced but only separated from other elements and made available for human use. The author of this thesis is aware of these differences but in order to increase the readability for a non-technical audience these simplifications or inaccuracies are deliberately accepted.

## 4.1 Explanation of the technologies and their potential areas of application

The combination of hydrogen and fuel cells is an umbrella term for many diverse technologies. Not only do hydrogen and fuel cells constitute two different technologies that can be applied independently from each other but also both include numerous technical applications that can but do not have to be used together. There is a myriad of handbooks explaining all diverse types of applications in the area of H & FC. It would go beyond the scope of this thesis to provide an exhaustive overview of this technological area. Furthermore, an exhaustive overview of all the existing technical applications is not necessary for the understanding of this thesis. Rather, this subchapter is to explain the working principles and the potential areas of application of those H & FC technologies that most handbooks focus on and that are more prominent in political discussions.

First, the production, storage and distribution of hydrogen are explained in detail. The main point is that hydrogen is not an energy source but an energy carrier. Therefore, issues of production, storage and distribution arise and diverse technologies have been developed to deal with them. Second, the working principles of diverse types of fuel cells are illustrated. In a nutshell, all types of fuel cells are energy conversion technologies and as such they convert one form of energy such as for instance chemical, electric or thermal into another one. Third, the more prominent areas of application for the combination of H & FC are outlined. Although hydrogen and fuel cells do not have to be used together, they are often mentioned in the same breath as their combination provides the opportunity of generating heat and electricity for buildings and vehicles without GHG emissions. It is for this reason that the combination of hydrogen and fuel cells has attracted a great deal of attention. Therefore, the third subheading will focus on outlining application areas of the combination of

H & FC instead of providing an exhaustive overview of all the specific areas of application for either hydrogen or fuel cells.

*Hydrogen production, storage and distribution*

Hydrogen is a gaseous element ($H_2$). However, it barely exists in its pure, gaseous form in free nature (Zini and Tartarini 2012, 15). Most often it is found in a more stable form and bound to either oxygen or carbon atoms (Dincer and Joshi 2013, 1). The combination of hydrogen and oxygen atoms results in the chemical formula of $H_2O$ and thus in the substance that is commonly known as water. The combination of hydrogen and carbon atoms results in hydrocarbon compounds which include diverse substances such as natural gas, crude oil and coal differing with regard to their ratio of carbon and hydrogen atoms. In addition, hydrocarbons can also be found in trees and plants or in different types of biomass. However, it is not necessary to go deeper into the details at this point. Rather, the main point is that hydrogen always has to be separated from other elements and that this process of separation requires the use of primary energy sources as will be explained in more detail in the following paragraphs.

Hence hydrogen can be conceived of as a means of energy storage rather than as a source of energy. Indeed, hydrogen constitutes a secondary energy carrier whose production requires the use of primary energy sources such as renewable energies, fossil energies or nuclear energy (Behrens 1986, 1, 20, 21; Dincer and Joshi 2013, 7). A wide range of diverse technologies has been developed to separate hydrogen from other elements. The most common hydrogen production methods are 1) steam reforming of hydrocarbons, 2) gasification of solid fuels, and 3) water splitting by electrolysis (Bertram 2011, 130; Zini and Tartarini 2012, 16).4 Steam reforming means to obtain hydrogen from gaseous fuels such as methane with the help of heat (Zini and Tartarini 2012, 16). In contrast, the gasification of

4 See (Dincer and Joshi 2013, 7–20) or (Zini and Tartarini 2012, 16–20) for a more thorough overview of the existing technologies for hydrogen production.

coal or biomass requires the input of heat to obtain hydrogen (Bertram 2011, 130; Zini and Tartarini 2012, 16). Finally, in the process of electrolysis electrical energy is used to split water into hydrogen and oxygen (Zini and Tartarini 2012, 29).

All three hydrogen production methods differ significantly not only with regard to the technical/chemical procedure but also with regard to their environmental impact. It is crucial to distinguish between $CO_2$ free, $CO_2$ neutral and $CO_2$ emitting hydrogen production pathways. A completely $CO_2$ free hydrogen production can only be achieved with the help of renewable and non fossil energy sources such as, for instance, solar or wind energy. $CO_2$ free means that during the whole production chain no $CO_2$ emission are emitted (Pant and Gupta 2008, 22). In contrast, $CO_2$ neutral hydrogen production means that $CO_2$ emissions are only emitted to the same amount as $CO_2$ is absorbed from the atmosphere. This can be achieved with photobiological hydrogen production from biomass. Hereby the biomass plants absorb as much $CO_2$ from the atmosphere while they grow as is later on emitted when they are combusted (Bauer 1986, 200, 201; Happe and Müllner 2004, 154, 155; National Research Council 2008, 10). Finally, $CO_2$ emissions are emitted when hydrogen production is based on fossil energies which is the case in steam reforming with natural gas or in the gasification of coal (National Research Council 2008, 6–9; Zini and Tartarini 2012, 16, 17). Nevertheless, the process of steam reforming during which $CO_2$ emissions are released into the atmosphere is the most prevalent hydrogen production method at present (Bertram 2011, 130; Zini and Tartarini 2012, 16), while emission free hydrogen production via electrolysis only plays a marginal role due to its energy intensity and high costs (Bertram 2011, 130).

The question of hydrogen storage is deeply connected to its distribution and use. If hydrogen is to be used as a fuel in the transport sector and hence has to be kept onboard the vehicle, it is most common to store it either in a gaseous form compressed at 350 or 700 bar or in a liquid form at cryogenic (low temperature) conditions at -253 $^{o}C$.[5] Liquid hydrogen can be stored at lower weight and volume per unit energy compared to compressed hydrogen. However, liquid hydrogen comprises a boil-off effect (loss of hydrogen) and the

5 Chemical and physical storage are other, less common ways of hydrogen storage onboard of vehicles.

liquefaction of hydrogen requires energy (actually 30% of the energy contained in liquid hydrogen) which leads to the fact that the fuel cycle energy efficiency is significantly lower for liquid hydrogen than for gaseous hydrogen (National Research Council 2008, 14, 15; Pant and Gupta 2008, 25, 26). Also for its use in stationary applications, hydrogen has to be stored either in a gaseous or in a liquid form. However, hydrogen storage for stationary applications is widely perceived as less problematic as it can be stored in much larger volumes with a row of diverse technologies.

When it comes to hydrogen distribution, there are three main options which differ with regard to hydrogen storage, production and use. First, hydrogen could be centrally produced on a large-scale and stored in a gaseous form which would allow distribution through pipelines. Second, a central, large-scale hydrogen production would also allow distribution via trucks, rails, barges and ships for both gaseous and liquefied hydrogen (Bertram 2011, 131). Third, hydrogen could be produced onsite that is to say directly at the place of its usage. This would allow using the existing infrastructure for the distribution of liquid energy carriers like ethanol and methanol which can be reformed to hydrogen at the end point of use (Gao and Krishnamurthy 2008, 341). All three ways, of course, come along with different economic and ecological pathways depending on the distance of transportation and on the quantity of the hydrogen that is to be distributed (Bertram 2011, 132; Zini and Tartarini 2012, 26, 27). In fact, even the proponents of H & FC describe the high costs of hydrogen production and distribution as one of the main hurdles in the commercialization of these technologies. Therefore, the development of forecasts and scenarios on the future development of the costs of hydrogen supply have played a key role in the co-production of EU H & FC policy and expertise as will be illustrated in chapter 7.

Furthermore, it should be noted, that the production, storage, and distribution of hydrogen does not come without risks and dangers. Indeed, hydrogen is a highly flammable gas which is why many of its critics consider its use as a fuel in passenger vehicles as too dangerous. The main point is that hydrogen leakages from vehicle tanks or any other means of hydrogen storage can lead to dangerous explosions as it is not only highly flammable but also has a high energy density per unit weight. Above all when hydrogen is mixed with air at a particular ratio, a dangerous and highly explosive hydrogen-air mixture can cause severe damages. Therefore, the critics of H & FC not only fear the explosions that might result from crashes of hydrogen fuelled vehicles but also hydrogen leakages from vehicles that are parked in garages as these could result in the gathering of extremely dangerous hydrogen-air mixtures under the roof of the garage. In addition, hydrogen is an odourless and colourless gas so that a potential leakage could not be detected by the human senses of the owner of the car. Therefore, however, technical sensors for the detection of hydrogen leakages are being developed (Joint Research Centre 2014b). Without going further into the details on the safety of hydrogen, this paragraph should briefly illustrate that there are safety concerns with the usage of hydrogen. These safety concerns have also played a role in the political discussions of H & FC during the preparations of the EC's eighth Framework Programme in 2012 and 2013 as will be outlined in chapter 9.

Hence the preceding paragraphs have highlighted the complexity of the development of a hydrogen infrastructure. Furthermore, they have also indicated the plethora of technological choices that have to be made and the large number of actors potentially affected by them. The development of a hydrogen infrastructure touches upon the interests of both large power companies that have to supply the energy for hydrogen production and consumers that have to fuel their cars with hydrogen.

*Working principles and types of fuel cells*

Fuel cells are an energy conversion technology that is to say they convert chemical energy from a fuel (energy carrier) into electricity through a chemical reaction. Although there are diverse types of fuel cells, all of them consist of a negative side, the so-called anode, and a positive side, the so-called cathode. In between the negative and the positive side is an electric conductor, the so-called electrolyte, which allows the electric charges to move between the two sides of the fuel cell. More specifically, the electrolyte is a substance that allows ions to pass through while it prevents electrons from passing through. Understanding the mechanism of the electrolyte is the key for understanding the more general process of electricity generation in a fuel cell that consists of two chemical reactions at the interface of the anode and the electrolyte and at the interface of the electrolyte and the cathode as outlined in the figure beneath.

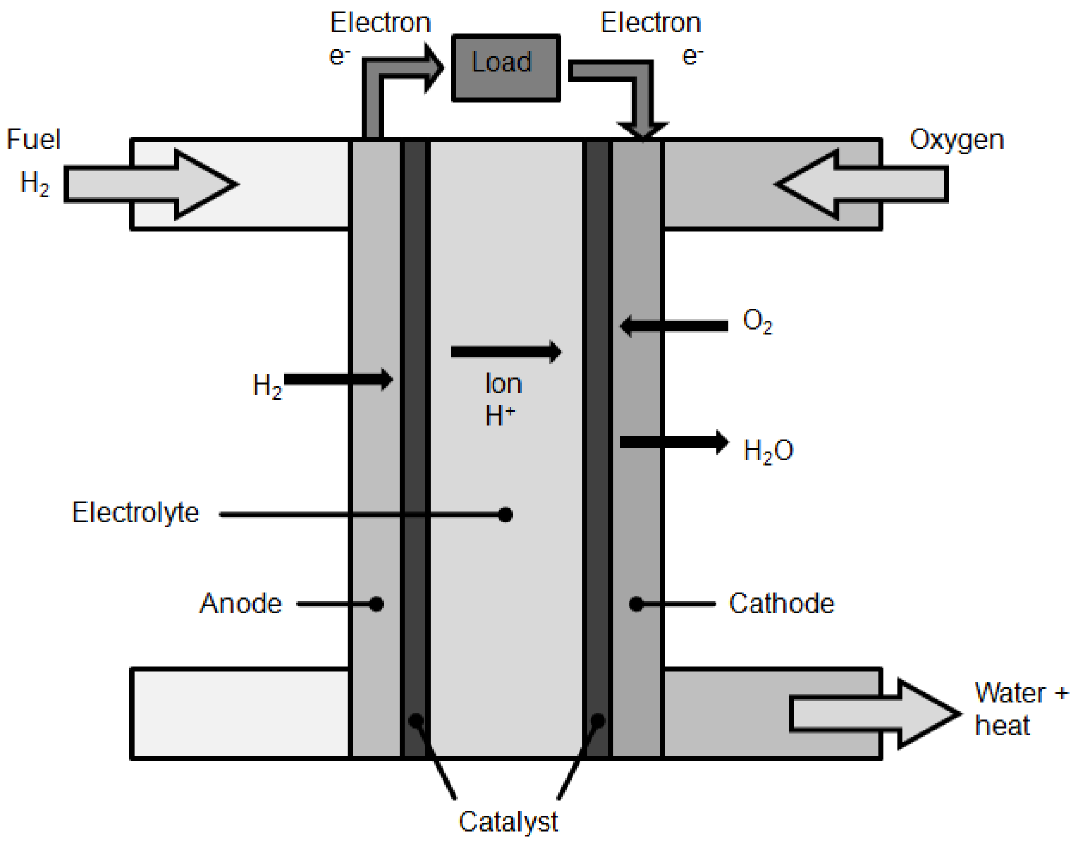



**Figure 6**, Electricity generation in a fuel cell

Source: (Adapted from Bertram 2011, 104)

First, the fuel used to power the fuel cell (which is hydrogen in the figure above), is oxidized at the anode by a catalyst so that a positively charged ion travels through the electrolyte while the negatively charged electron that cannot enter the substance of the electrolyte moves through an external wire and generates electricity in this way (Bertram 2011, 104). While the electron moves via an external wire to the cathode, the ion travels through the electrolyte. Once both have reached the cathode, they reunite and the second chemical reaction takes place among the ion, the electron, and a third chemical element, as, for example, oxygen. This process creates either water (as in the figure above) or carbon dioxide, depending on the fuel used, as the byproducts of electricity generation in a fuel cell (Zini and Tartarini 2012, 43, 44). Due to the second law of thermodynamics, another byproduct of the conversion of chemical energy into electrical energy in a fuel cell is waste heat. This heat can be used in combined heat and power fuel cell systems to provide heating for all kinds of buildings.

However, the primary objective of a fuel cell remains the generation of electricity. For this purpose, fuel cells are usually used in a stack which means that several fuel cells are combined and used simultaneously in order to increase the amount of electricity generated (Bertram 2011, 105). Fuel cells can be connected in serial and in parallel circuits or in a combination of both to yield either a higher voltage or to supply a higher current depending on the purposes of the application. As a rule of thumb it can be said that a higher number of fuel cells connected in a stack increases the voltage, while a larger surface area of the cells increases the current.

There are many different types of fuel cells that can be distinguished by their type of electrolyte and by their operating temperature as the figure below illustrates:

| **Type** | **Electrolyte** | **Operating Temperature** |
|---|---|---|
| Alkaline Fuel Cell (AFC) | Potassium hydroxide in a water solution | 60-80° C |
| Polymer Membrane Fuel Cell (PEMFC) | Polymer membranes | 80° C |
| Direct Methanol Fuel Cell (DMFC) | Polymer membranes | 80-130° C |
| Phosphoric Acid Fuel Cell (PAFC) | Phosphoric acid | 200° C |

| | | |
|---|---|---|
| Molten Carbonate Fuel Cell (MOFC) | Lithium potassium carbonate salt | 650° C |
| Solid Oxide Fuel Cell (SOFC) | Ceramic material (zirconium oxide) | 800-1000° C |

**Table 2**, Main types of fuel cells

Source: (Adapted from Bertram 2011, 106)

All types of fuel cells can be powered by a range of different liquid and gaseous fuels such as hydrogen, diesel, methanol, ethanol, natural gas, biofuels etc. However, it should be noted that a completely emission free energy cycle from the primary energy source to electricity generation in a fuel cell can only be achieved through hydrogen produced without emissions with the help of renewable energies. It is this ecological potential of the combined usage of hydrogen and fuel cells that their promoters most often refer to and the reason why these actually different technologies are often mentioned together.

*Application areas of hydrogen and fuel cell technologies*

The following illustrations will focus on outlining the main areas of application for the combination of hydrogen and fuel cell technologies instead of describing all potential areas in which hydrogen or fuel cells could be applied separately. The main reason for this is that the ecological potential of these technologies, and their political relevance resulting thereof, stems from their combination. Hydrogen can be generated with renewable energies and converted into electricity by a fuel cell without causing any emissions during the entire process. Hence most political attention has been paid to the combination of hydrogen and fuel cell technologies due to its ecological potential to provide an emission-free energy cycle from primary energy source to electricity supply.

However, it has to be emphasized that not only hydrogen and fuel cell technologies are not ecological *per se* but also that their combination is not. In fact, the crux is the production of hydrogen because GHG emissions are caused if hydrogen is produced by other means than renewable energies. Once hydrogen is produced, it can be used in a fuel cell to generate electricity without emissions. Of course, fuel cells can also be powered by other fuels than hydrogen but again this would cause GHG emissions. Therefore, the ecological potential of the combination of hydrogen and fuel cell technologies is firmly tied to the development of renewable energies.

Three broader areas of application for the combination of hydrogen and fuel cell technologies can be distinguished: 1) transport, 2) stationary, and 3) portable (Bertram 2011, 106, 107; TÜV SÜD 2014v). In the transport sector H & FC provide the opportunity of an emission free, sustainable mobility. Hydrogen is discussed as a fuel due to several of its properties like combustion efficiency, high energy content per unit of mass, wide range of flammability and so on (Pant and Gupta 2008, 8–12). When used in a fuel cell, hydrogen is converted into electricity that is fed into the electric drivetrain of the vehicle. In order words, hydrogen would replace gasoline or diesel as fuel and the fuel cell would replace the internal combustion engine as propulsion system. In this way, H & FC could be used to provide the energy needed to move all kinds of vehicles such as buses, lorries, cars, two-wheelers or forklifts.

Furthermore, H & FC do not have to be used as the main propulsion system for vehicles but could also be applied as range extenders or auxiliary power units. H & FC could function as a range extender in hybrid vehicles powered by a battery. In this case, they would constantly recharge the battery in order to increase the overall range of the vehicle. If H & FC are applied as an auxiliary power unit, however, they would only satisfy the demand of electricity at peak times that can be caused by specific devices such as, for example, seat heating systems (Bertram 2011, 107). However, in both cases, as a range extender and as an auxiliary power unit, H & FC could not guarantee an emission free mobility, of course, as they do not constitute the main propulsion system of the vehicle in question but only serve as an additional source of power.

In the stationary sector combined heat and power fuel cell systems powered by hydrogen can be applied to provide electricity and heat in industrial and residential buildings in an emission free energy cycle from primary energy source to electricity supply. They can be used to run small-scale heating devices for private households and large-scale heating devices for the industry. In fact, such fuel cell systems can provide electricity and heat for all kinds of buildings from large factories to remote weather stations. Furthermore, they can also serve for backup or emergency power systems in hospitals, scientific laboratories, data centres or other places at which continued, uninterrupted power supply is of great importance.

In this respect it should also be noted that fuel cells can contribute to a more decentralized and distributed energy system as they provide the opportunity to generate electricity directly at the place where it is needed, while currently electricity is mostly generated in large, centralized facilities and often has to travel large distances to reach the consumer. Hence H & FC not only provide the opportunity for more efficient and clean electricity generation but rather allow for a more radical transformation of the energy system from centralized electricity generation to local electricity generating units. Proponents of fuel cells argue that distributed electricity generation would also contribute to a higher security in energy supply as local electricity generation not only releases the overall grid but also makes consumers more independent of the overall grid.

The third main application area for the combination of hydrogen and fuel cells consists of rather small, portable devices such as cell and smart phones, laptops, tablets etc. Proponents of H & FC argue that these technologies could solve the problem of short battery life in all these devices. Fuel cells powered by hydrogen could either be integrated into these devices replacing batteries as the main source of power or they could be used as an auxiliary, external device to recharge the smart phone or the laptop. Either way fuel cells powered by hydrogen provide the potential of using these devices in several weeks without recharging.

In addition to these three main areas of application, energy storage as another potential use of hydrogen has gained increased popularity over the past years. The main argument is that the politically envisaged higher share of renewable energy sources in the total electricity generation will lead to an increased need for means of energy storage as the intermittent nature of renewable energy sources such as wind or solar power does not always correspond to the demand of electricity. Hence there will be times of energy surpluses that raise the need for means of energy storage which then could be used to meet the demand of electricity when the sun does not shine and when the wind does not blow. Hydrogen could serve as the perfect means to bridge these gaps between supply and demand of electricity as its proponents argue. Surpluses of electricity from renewable energies could be used to produce hydrogen which could be converted into electricity by fuel cells in times of low availability of renewable energies. In this way H & FC could contribute to a higher security in energy supply in spite of the losses of energy caused by the production of hydrogen and its later conversion into electricity.

However, it is exactly these losses of energy that are at the centre of much of the critique of H & FC. In fact, both the production of hydrogen and its usage in fuel cells in order to generate heat and electricity constitute processes of energy conversion. Hence, according to the second law of thermodynamics, a certain amount of energy is lost in both processes of energy conversion in the form of heat. In fact, how high these losses are and whether they are too high or not are two of the main issues in the political discussions of H & FC. The critics of H & FC argue that too much of the primary energy used for hydrogen production is lost during the two processes of energy conversion so that only a rather low amount of energy can be used for vehicle propulsion in the end. Their main point is that H & FC vehicles constitute a waste of energy and that other, much more energy efficient, technologies could be used for vehicle propulsion, too. In particular battery electric vehicles were very often pointed out as a much more energy efficient alternative to achieve a sustainable and emission-free transport system than H & FC vehicles as will be outlined in more detail in chapter 7.

This brief summary of application areas should illustrate that H & FC could function as the key components of a whole energy system in which hydrogen as an energy carrier could be used as a means for energy transport and energy storage (Federal Ministry of Education and Research 1988, 11) and fuel cells could be used to generate power and electricity as well as to run small-scale heating devices for private households and large-scale for the industry. In a nutshell, H & FC could be used for almost every technical device that consumes energy. However, as almost none of these technologies are commercialized, yet, research and development work is performed on the vast majority of them (cf. Behrens 1986; Federal Ministry of Education and Research 1988). Furthermore, the preceding paragraphs have illustrated that the future potential of H & FC to bring about an emission-free energy and transport system does not come without dangers and risks so that the development of H & FC has also given rise to critique from various actors.

## 4.2 Historical development until 2000

The historical development of H & FC constitutes a prime example of the non-linear nature of scientific and technological development as hydrogen and fuel cells are not really new inventions but rather look back on a long history with a lot of ups and downs. Historical milestones and new discoveries in the area of H & FC which attracted a good deal of societal attention have been followed by periods of time in which the actual existence of H & FC was almost forgotten. Furthermore, the historical development of H & FC has been accompanied by serious drawbacks at various points in time which caused severe damage to the societal reputation of these technologies. Above all the explosion of the Hindenburg Airship in 1937 has left a lasting imprint on the reputation of H & FC up to the present day. The following paragraphs will draw upon various sources in order to provide a brief summary of the historical development of H & FC and its many ups and downs. A more thorough description of the recent developments in the European policy on H & FC, which this thesis investigates, will be provided in the subsequent subchapter.

However, before a brief summary of the historical development of H & FC can be provided a few remarks have to be made to clarify how this story will be told. The reader should for instance note that the historical development of H & FC could be told in diverse ways. One could, for example, focus on the development of the different technologies required for the production of hydrogen. However, most authors highlight the development of H & FC applications with a clear focus on the transport sector. This thesis is to follow this representation of the history of H & FC in order to illustrate how the history of H & FC is told at present which is more important for the purposes of this thesis than the actual technical development. Furthermore, the development of H & FC gives rise to controversy in the literature on what specific inventions should be attributed to what persons. Therefore, it has to be emphasized that this subchapter does not constitute an attempt to rewrite the history of H & FC in favour of certain persons or to the disadvantage of others. Rather, the main purpose is to provide the reader with a basic understanding of the general trends in the historical development of H & FC. In a similar vein, the following descriptions do not claim to be exhaustive but rather to portray specific events and projects that reflect the broader trends in the history of H & FC.

The historical development of H & FC can be split into three different periods of time. First, the development of H & FC is characterized by individual inventions with large time distances in between until the late 1950s. Second, in the 1960s and 1970s, the initiatives promoting hydrogen and fuel cell technologies started to increase in number all over the world due to the successful application of H & FC in space programmes and a growing environmental awareness. Third, the investments from public and private actors in H & FC increased considerably in the 1980s and 1990s and boosted the development. The following paragraphs will describe the three periods in time in more detail. In addition to these three periods of time in the development of H & FC, a further section at the end of this subchapter will illustrate the drawbacks that have accompanied the development of these technologies in order to provide a balanced account of the history of H & FC.

*18$^{th}$ century – late 1950s: Individual inventions*

Both the development of hydrogen and that of fuel cells began with basic inventions by individual persons, followed by further individual inventions and wide temporal intervals in between during which the technologies did not gain any societal attention. The first basic inventions in the area of H & FC have been made over 200 years ago. In 1766 Henry Cavendish was the first to identify and isolate hydrogen as a chemical element. 15 years later in 1781 Antoine Lavoisier reproduced Cavendish's experiment and gave the chemical element it's the name that it still bears today: hydrogen (Zini and Tartarini 2012, 13). The first hydrogen-driven combustion engine was constructed by Francois Issac de Rivaz in 1807 and used to power a four-wheeled vehicle (TÜV SÜD 2014k).

The mechanisms behind present-day fuel cells were discovered in 1838 by the German-Swiss chemist Christian Friedrich Schönbein. Building on Schönbein's findings, the British lawyer and natural scientist Sir William Grove developed the first fuel cell in 1839 (Bertram 2011, 103; FuelCellToday 2014; TÜV SÜD 2014n; Zini and Tartarini 2012, 13). However, Grove called his invention a gas battery and it was not until 1889 that the fuel cell gained its actual name from Ludwig Mond and Charles Langer who further developed Grove's invention (FuelCellToday 2014). Thereafter, the fuel cell disappeared from the stage for quite some time and it was not until the 1950s that it should attract societal attention again (TÜV SÜD 2014n).

In the meantime, several vehicles with hydrogen-powered combustion engines have been developed. In 1860 Étienne Lenoir built a three-wheeled experimental vehicle with a hydrogen-powered combustion engine (TÜV SÜD 2014o). In 1933 the Norwegian company Norsk Hydro developed a concept car with an internal combustion engine powered by hydrogen (TÜV SÜD 2014s). In 1941 a further concept car with a hydrogen-powered combustion engine named GAZ-AA was built in the Soviet Union (TÜV SÜD 2014l). The time distance between the constructions of the vehicles indicates once more the non-linear nature of scientific and technology development.

In 1932 Francis Thomas Bacon developed the first model of an alkali electrolyte fuel cell but it was not until 1959 that he actually demonstrated a practical 5 kW fuel cell system. This development was followed by the construction of the first vehicle with a fuel cell propulsion system in 1959:An agricultural tractor of the company Allis-Chalmers was equipped with a 15 kW fuel cell by Harry Karl Ihrig (FuelCellToday 2014; TÜV SÜD 2014a). Thereafter, Allis-Chalmers developed a number of further fuel cell powered vehicles including a forklift truck, a golf cart and a submersible vessel in cooperation with the US Air Force (FuelCellToday 2014).

*Late 1950s -1979: Tailwind from space programmes and growing environmental awareness*

In the 1960s and 1970s space programmes and the oil crisis increased the efforts in the development of H & FC. The National Aeronautics and Space Administration (hereinafter NASA) started to develop fuel cells for its space missions in the late 1950s in cooperation with industrial companies (FuelCellToday 2014). First, the company Pratt and Whitney developed and successfully tested a hydrogen turbine as a propulsion system for rockets in 1959 (TÜV SÜD 2014t). Pratt and Whitney continued its cooperation with the NASA in the Apollo programme which ran from 1961 to 1972 (TÜV SÜD 2014b) and the first flight of a rocket powered by a Pratt and Whitney hydrogen-fuelled fuel cell took place in 1963 (TÜV SÜD 2014t).

The cooperation of the NASA with industrial partners also resulted in the invention of the Polymer Membrane Fuel Cell by Willard Thomas Grubb of the company General Electric in 1959 (FuelCellToday 2014). The Polymer Membrane Fuel Cell was further developed and later on used in the Gemini spaceflight programme of the NASA that ran from 1962 to 1966 (TÜV SÜD 2014m). The continuous focus on the development of fuel cells resulted in an improved power output. While the first fuel cells in the early 1960s had a power output of 1 kWe (TÜV SÜD 2014m) and 2.3 kWe (TÜV SÜD 2014b), the NASA space shuttles in the 1970s were equipped with 12 kWe fuel cells (TÜV SÜD 2014u). Furthermore, it should be noted, that also the Soviet Union and the European Union developed fuel cells for their space programmes (FuelCellToday 2014; TÜV SÜD 2014c).

Hence the space programmes had a significant impact on the development of H & FC as these technologies were successfully applied in spacecrafts where they not only demonstrated their technical functionality but also gained acceptance as key technologies that enabled mankind the travel to the moon. Of course, the space programmes were undertaken for political and military purposes and not for the sake of H & FC development. Still, they improved the performance and power output of H & FC.

The second event that had a great impact on the development of H & FC in this period of time was the oil crisis in 1973 and the increased environmental awareness that resulted thereof. Of course, this increased environmental awareness did not specifically support the development of H & FC but rather that of alternative energy technologies that should dissolve the transport and electricity sector from their reliance on crude oil. H & FC were among these technologies and benefitted from the general trend in favour of more ecological technologies.

The increased concerns over the availability of oil triggered the development of new hydrogen-fuelled vehicles by diverse organizations from Germany, Japan and the USA (FuelCellToday 2014). The Musashi Institute of Technology at the University of Tokyo for instance built and tested several prototypes of hydrogen-powered cars from 1974-1977 (TÜV SÜD 2014p, 2014q, 2014r). The American businessman and scientist Roger E. Billings equipped several buses, tractors and forklifts with hydrogen-fuelled combustion engines and tested these in 1976 and 1977 (TÜV SÜD 2014d, 2014e, 2014f, 2014g, 2014h, 2014i). However, not only individuals and research units of universities constructed prototypes of H & FC vehicles but also large car manufacturers such as BMW (TÜV SÜD 2014j).

While all of these vehicles were equipped with hydrogen-fuelled combustion engines, the striving for energy-efficient technologies also brought about advances in fuel cell technologies. For example, the Phosphoric Acid Fuel Cell, invented in the 1960s, was further developed through demonstrations of large stationary units for off-grid power in the 1970s which improved both its stability and performance. Furthermore, the development of the Molten Carbonate Fuel Cell was supported by funding from the US military and electrical utility companies (FuelCellToday 2014).

*1980 – 2000: Increasing investments from public and private actors*

The development of H & FC was accelerated considerably in the 1980s and 1990s through increased activities by governments and private companies. Public authorities all over the world made funding available for the development of H & FC, more and more private companies started to invest in these technologies and new companies solely dedicated to H & FC were founded. Furthermore, the first small-scale demonstration projects with a specific focus on the development of H & FC were launched. The following paragraphs cannot provide an exhaustive overview of this development but rather outline some specific projects and events which illustrate the broader trends.

The foundation of the Canadian company Ballard Power Systems in 1979 constitutes an important event in the history of the development of H & FC. Although initially focused on lithium batteries, Ballard began to develop fuel cells in 1983 and was to become one of the world's leading fuel cell suppliers in the following decades. Ballard not only provided fuel cell systems for demonstration projects all over the world but also formed a strategic alliance with the car manufacturers Daimler and Ford which further boosted the research and development activities on H & FC (Ballard 2014).

Some of the first results of the strategic alliance between Ballard and Daimler could be seen in the NECAR project. NECAR, an abbreviation for "New Electric Car" and "No

Emission Car", was initiated and accomplished by Daimler in cooperation with Ballard. The objective of the project was to develop a fuel cell propulsion system for vehicles. For this purpose, five fuel cell-powered car prototypes were constructed between 1994 and 2000. The project was carried through in Germany where Daimler fitted the fuel cell systems delivered by Ballard into different car bodies of its regular models (Daimler 2014). Ballard also delivered the fuel cell systems for a test programme with six 40 feet fuel cell buses in Chicago in the USA and in Vancouver in Canada in the time period of 1998-2000 (Eudy, Chandler, and Gikakis 2007, 2).

However, the 1980s and 1990s not only saw a focus on transport applications but there were also diverse projects that aimed at developing more efficient hydrogen production methods. HYSOLAR for instance was a German-Saudi-Arabian research, development, and demonstration program to assess the chances of $CO_2$-free hydrogen production from solar energy in Saudi Arabia and its subsequent transportation to Germany (Brinner and Steeb 2001, 1). The program ran from 1985 to 1995 and had a budget of 83.5 million Deutsche Mark which was co-financed by both countries (Brinner and Steeb 2001, 1, 2).

Also the European Union has funded demonstration projects on H & FC in the 1990s. The Euro-Quebec Hydro-Hydrogen Pilot Project for instance was a European-Canadian demonstration project for H & FC that was carried through in the time period of 1986-1998 (Bahbout, Gretz, Kluyskens, Sandmann, et al. n.d., 2). The project was coordinated by the Joint Research Centre of the EC and the government of Québec and was one of the largest demonstration projects at the time being with an overall budget of € 45 million (Gretz, Drolet, Kluyskens, Sandmann, et al. 1994, 169, 174). The initial idea of the project was to generate hydrogen in an emission-free way via electrolysis with hydropower in Québec. Thereafter this hydrogen should be shipped to Europe where it could be used for electricity and heat generation and vehicle and aviation propulsion (Gretz, Drolet, Kluyskens, Sandmann, and Ullmann 1994, 169). However, in the first years of the planning phase it became clear that the actual implementation of the project would require an additional Deutsche Mark 1.5 billion which could not be mobilized. Therefore, the focus of the project was shifted from hydrogen production to its application in the stationary and the transport sector. Several hydrogen-powered buses and combined heat and power plants have been tested in various European countries (Bahbout, Gretz, Kluyskens, Sandmann, and Wurster n.d., 2).

However, while the EU has funded individual demonstration projects for H & FC since 1986 as outlined in more detail in subchapter 2.3, it did not have any specific H & FC policy until the first years of the new millennium. The development of a specific EU H & FC policy and the simultaneous production of expertise on H & FC in the years of 2002-2014 will be illustrated in the next subchapter. First, however, the drawbacks in the development of H & FC are explained under the following subheading in order to provide a balanced account of the history of H & FC.

*Drawbacks in the development of H & FC*

The historical development of H & FC has always been accompanied by various types of drawbacks which have temporarily brought the technological development to a halt and/or caused severe damage to the societal reputation of H & FC. The preceding three subheadings, however, have primarily focused on describing the milestones in the historical development of H & FC until 2000 in order to provide the reader with a better understanding of the promotion of these technologies in the EU in the years of 2000-2014 which constitutes the empirical case investigated in this thesis. Of course, these milestones and breakthroughs in the development of H & FC have often been preceded, accompanied, or followed by failed experiments and research projects which have not brought about technological progress but rather disappointment and disillusionment. However, while failed and successful research projects are part of the development of any technology, the history of H & FC also includes some key events which have left a lasting imprint on these technologies up to the present day. Indeed, some of the present critique of H & FC relies on safety concerns with hydrogen which have been fuelled by various hydrogen explosion hazards in the twentieth century. Therefore, some of these hazards are described in more detail in the following paragraphs.

The most severe accident in terms of fatalities that many people connect to hydrogen was the Hindenburg disaster in 1937. The Hindenburg was a German hydrogen airship which means that it used hydrogen as lifting gas. In May 1937 the Hindenburg was with its crew and 97 passengers on the way from Frankfurt in Germany to the Naval Air Station at Lakehurst, New Jersey, in the USA. Shortly before landing in the USA, the Hindenburg caught fire which quickly spread out all over the airship and in around half a minute caused the Hindenburg to crash into the ground. The accidents resulted in the loss of 36 lives among which passengers, crew members, and one worker on the ground. As a result, the Hindenburg disaster marked the end of the airship era (Grossman 2014b).

In fact, there are many different theories on what might have caused the fire on the Hindenburg and the causes of this fire give rise to controversy up to the present date (e.g. Daily Mail 2013; Grossman 2014b). Irrespective of what actually has caused the fire, many people associate the Hindenburg disaster with leaking hydrogen that somehow caught fire which, due to hydrogen being extremely flammable, quickly spread out so that the entire airship was on fire within half a minute. Hence the Hindenburg disaster has brought hydrogen the reputation of being explosive and dangerous. Indeed, even in the preparations of the eighth FP of the EC in 2012 and 2013 some people still associated hydrogen with the Hindenburg disaster and criticized the use of hydrogen as a fuel in vehicles and at refuelling stations as too dangerous as will be illustrated in chapter 9.

These associations of hydrogen with explosiveness and danger have also been fuelled by further hydrogen explosion hazards in the last and in the current century. The Hindenburg disaster was for instance preceded by several other hydrogen airships that exploded or burned down to the ground in the first decades of the twentieth century (Grossman 2014a). In 1985 a hydrogen-air mixture caused a severe explosion with two fatalities at an ammonia plant in Norway. The explosion was caused by the breakdown of a water pump which resulted in a leakage of hydrogen that in less than half a minute was ignited by a hot bearing and brought to explosion (Bjerketvedt and Mjaavatten 2005, 1). Also the explosion of the Challenger space shuttle in 1986 in which all seven crew members died is often associated with leaking hydrogen (KSC 2014; US Department of Transportation 2010, 5). More recently, three devastating hydrogen explosions during the nuclear accident in Fukushima, Japan, in 2011 reinforced the image of hydrogen being a dangerous and highly explosive gas (Natural Resources Defense Council 2014, 4) although, of course, the initial cause of the nuclear accident was a Tsunami that was caused by an underwater earthquake.

This list of hydrogen explosion hazards is not exhaustive but should illustrate why many of the present critics of H & FC consider the use of hydrogen as a fuel in vehicles and at refuelling stations as dangerous and risky. In fact, hydrogen explosions have not only occurred in airships and space shuttles but there are also examples of accidents at hydrogen refuelling stations. In August 2010 for instance there was a hydrogen explosion at a hydrogen refuelling station at the Rochester Airport in the state of New York in the USA. This hydrogen refuelling station serves a fleet of service vehicles at the airport which are powered by hydrogen as a fuel. The explosion occurred when hydrogen was supplied to the refuelling station from tank trucks. Two people were injured and the Rochester Airport was closed for several hours due to the fire that was caused by the explosion (US Department of Transportation 2010, 6, 7).

Hence the preceding paragraphs have illustrated that the historical development of H & FC not only consists of technological breakthroughs which have brought these technologies closer to commercialization but rather the history of H & FC also encompasses several drawbacks which have caused severe damage to the societal reputation of these technologies up to the present day. Above all the image of hydrogen being a highly explosive and dangerous gas was still alive in the political debates on H & FC in the years of 2012 and 2013 as will be explained in more detail in chapter 9. First, however, the next subchapter explains in how EU H & FC policy reflects broader trends in European research policy.

## 4.3 Hydrogen and fuel cell policy exemplifying the innovation turn in the governance of European research policy

This subchapter illustrates in how far the promotion of H & FC by the EC reflects broader trends in EU R&I policy. For this purpose it is split into two subheadings. First, it will be outlined how the development of H & FC along with many other technologies has been funded through diverse programme themes of the EU Framework Programmes before 2002. Hence there was no holistic, overarching strategy for the development of H & FC shared by many diverse actors but rather individual projects have been carried out with different objectives. This was the usual approach for the development of many technologies before the innovation turn. Hence the main point is that the funding of R&I projects in the area of H & FC exemplified the usual development of different technologies through the Framework Programmes of the EU until the Lisbon Council in March 2000 which brought about the innovation turn in European research policy.

Second, it will be shown how the development of H & FC, along with that of a row of other technologies, has been caught by the wave of the innovation turn in the EU. This shift towards innovation policy at the turn of the millennium resulted in the development of several new R&I policy instruments that were to promote a more holistic approach to innovation and to increase the competitiveness of the European industry. Two of these new instruments have been applied for the promotion of H & FC. This illustrates that the development of H & FC, along with that of a number of other technologies, can serve as a prime example of how the EC attempts to implement its new focus on innovation in research policy after the Lisbon Council in March 2000.

Thus both parts of this subchapter illustrate in how far general conclusions on the governance of EU R&I policy can be drawn from a study of EU H & FC policy. It is shown that the case of H & FC provides a good example of how the development of specific technologies is governed in the EU Framework Programmes which constitute the main instrument of European R&I policy. Hence a study of EU H & FC policy can highlight how the general political debate can affect the application of certain policy instruments for the promotion of specific technologies in the EU Framework Programmes. The case can also provide conclusions on how specific technologies are portrayed and in how far this affects the application of specific policy instruments for their promotion and their embedding in the overall R&I policy context. Simultaneously, it can be shown how the representation of specific technologies changes over time and in how far this change affects and is affected by the overall political debate. Furthermore, an investigation of EU H & FC policy could provide some first empirical results on the actual implementation and evaluation of the new policy instruments in EU R&I policy that have been neglected by the scholarly literature so far.

However, there are also limitations to the general conclusions that can be drawn from the case. An investigation of EU H & FC policy which is promoted through specific policy instruments in the EU Framework Programmes cannot provide conclusions on the launch of novel R&I organizations and institutions such as the European Research Council or the European Institute of Innovation and Technology. In contrast to specific R&I policy programmes which the EC sometimes can launch on its own, it plays a less important role in the launch of novel EU R&I organizations. Member States, however, proved to be powerful actors in the negotiations on the launch of novel EU R&I organizations, while they might not be involved in the decisions on specific EU R&I policy programmes. Therefore, the case of EU H & FC policy cannot provide any generalizations on the launch of novel EU R&I organizations. Furthermore, a study of EU H & FC policy cannot provide any insights on the overall development of these technologies but rather the results of the study are limited to the implementation of EU funded research projects. However, H & FC are also developed at research units of multi-national companies and in research projects funded by other sources.

*Situating H & FC in the Framework Programmes*

The EU has been funding R&I projects in the area of H & FC through its Framework Programmes since 1986 with a steady increase in the amount of funding over the years as the table beneath illustrates:

| FP 2 (1986-90) | FP 3 (1990-94) | FP 4 (1994-98) | FP 5 (1998-02) | FP 6 (2002-06) | FP 7 (2007-13) | FP 8 (2014-20) |
|---|---|---|---|---|---|---|
| 8 | 32 | 58 | 145 | 300 | 470 | 700 |

**Table 3**, Funding in the Framework Programmes dedicated to R&I projects in the area of H & FC (in € million)

Source: (European Commission 2006e, 9)

H & FC have mostly been funded through the energy schemes of the Framework Programmes. Of course, R&I projects have also been funded through intergovernmental European institutions such as EUREKA. However, the following illustrations focus on the Framework Programmes as these constitute the main instrument of EU R&I policy. The fourth FP for instance had an overall budget of € 13,215 million that was distributed among four activities: 1) Research, technological development and demonstration programmes, 2) Cooperation with third countries and international organisations, 3) Dissemination and optimisation of results, and 4) Training and mobility of researchers. The largest portion of the overall budget, € 11,496 million, was dedicated to the first activity which comprised fifteen thematic areas (European Commission 2001f). “Non nuclear energy” was one of these thematic areas with a share of € 1076 million or 8.1 % of the overall budget of FP 4. H & FC projects were mostly funded through this thematic area (European Commission 2000b).

EU expenditures on H & FC are documented in more detail from FP 5 onwards. FP 5 had a budget of € 13,700 million that was distributed among four activities and further research activities by the Joint Research Centre. The largest portion of the overall budget, €

10,843 million, was dedicated to the first activity “Research, technological development and demonstration” which was further split up into four themes. Most R&I projects on H & FC were funded under the fourth theme “Energy, Environment and Sustainable Development” that had a budget of € 2,125 million (European Commission 2014b). Furthermore, some R&I projects on H & FC were funded from the third theme “Competitive and Sustainable Growth” with a budget share of € 2,705 million and also the Joint Research Centre has carried through some R&I projects on H & FC from its budget of € 739 million (European Commission 2003c, 144, 2014b).

The sixth Framework Programme of the EU had an overall budget of € 16,270 million which was distributed among three main categories as the table beneath illustrates:

| | EUR million |
|---|---|
| **EC Framework Programme** | **16 270** |
| 1. Focusing and integrating Community research | 13 345 |
| 1.1 Thematic priorities[2]: | 11 285 |
| 1.1.1 Life sciences, genomics and biotechnology for health | 2 255 |
| *1.1.1.1 Advanced genomics and its applications for health* | *1 100* |
| *1.1.1.2 Combating major diseases* | *1 155* |
| 1.1.2 Information society technologies[3] | 3 625 |
| 1.1.3 Nanotechnologies and nanosciences, knowledge-based multifunctional materials and new production processes and devices | 1 300 |
| 1.1.4 Aeronautics and space | 1 075 |
| 1.1.5 Food quality and safety | 685 |
| 1.1.6 Sustainable development, global change and ecosystems | 2 120 |
| *1.1.6.1 Sustainable energy systems* | *810* |
| *1.1.6.2 Sustainable surface transport* | *610* |
| *1.1.6.3 Global change and ecosystems* | *700* |
| 1.1.7 Citizens and governance in a knowledge-based society | 225 |
| 1.2 Specific activities covering a wider field of research | 1 300 |
| 1.2.1 Policy support and anticipating scientific and technological needs | 555 |
| 1.2.2 Horizontal research activities involving SMEs | 430 |
| 1.2.3 Specific measures in support of international co-operation | 315 |
| 1.3 Non-nuclear activities of the Joint Research Centre | 760 |
| 2. Structuring the European Research Area | 2 605 |
| 2.1 Research and innovation | 290 |
| 2.2 Human resources and mobility | 1 580 |
| 2.3 Research infrastructures [4] | 655 |
| 2.4 Science and society | 80 |
| 3. Strengthening the foundations of the European Research Area | 320 |
| 3.1 Support for the co-ordination of activities | 270 |
| 3.2 Support for the coherent development of policies | 50 |

**Table 4**, The budget of Framework Programme 6

Source: (European Commission 2002f, 22)

Altogether R&I projects in the area of H & FC were funded by around € 300 million in FP 6 (European Commission 2006e, 9). Most of this funding, around 75% (energy short-medium term + energy medium-long term), came from the thematic priority “1.1.6.1 Sustainable energy systems” as illustrated by the figure below:

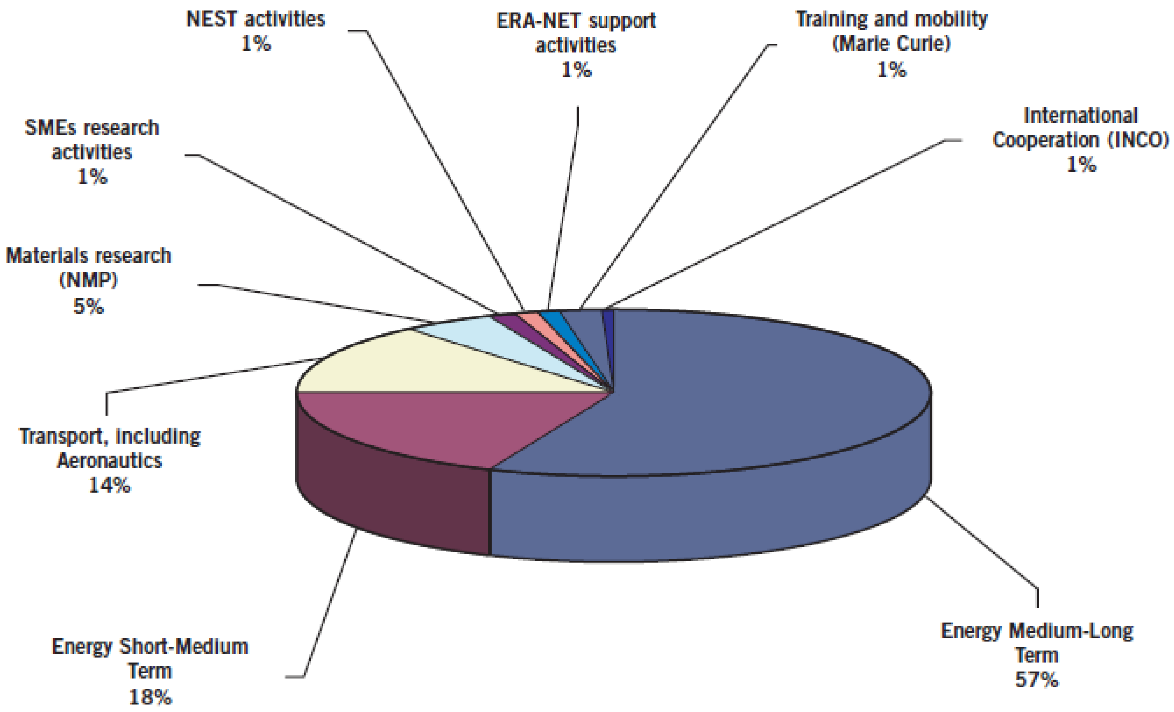



**Figure 7**, H & FC funding in FP 6 according to programme areas

Source: (European Commission 2006e, 8)

The illustrations above show that R&I projects in the area of H & FC have been funded under many different thematic schemes. But although the EU has been funding R&I projects in the area of H & FC since 1986 (European Commission 2013h), there was no specific EU H & FC policy before 2002. The main point is that before 2002 there has not been any overarching vision for the development of H & FC but rather individual R&I projects have been funded along with many other technologies that were regarded as energy-efficient and ecological. This was to change significantly with the beginning of FP 7 as the EC decided to launch a public-private partnership that was to fund R&I projects in the area of H & FC from its own budget. The launch of this public-private partnership was prepared during FP 6 through another novel policy instrument that was applied to foster the development of H & FC as will be outlined under the following subheading.

*The promotion of H & FC after the innovation turn in EU R&I policy*

The past decade has seen the introduction of several new policy instruments in EU R&I policy. Technology Platforms and Joint Technology Initiatives are two of the first and most important ones.[6] The European Commission launched the European Hydrogen and Fuel Cell Technology Platform (hereinafter HFP) in 2004 in the scope of the sixth FP together with nineteen other Technology Platforms:

| Theme/Objective | Technology Platforms |
|---|---|
| New technologies leading to radical change in a sector, if developed and deployed appropriately and in time | ***Hydrogen and Fuel Cells (HFP)*** |
| | European Nanoelectronics Initiative Advisory Council (ENIAC) |
| | Nanomedicine (Nanobiotechnologies for Medical Applications) |
| Reconciliation of different policy objectives with a view to sustainable development | Plants for the Future |
| | Water Supply and Sanitation (WSSTP) |
| | Photovoltaics |

6 Public Private Partnerships, European Innovation Partnerships and Joint Programming Initiatives are further novel policy instruments in EU R&I policy that, however, were introduced later on (European Commission 2013f).

| | |
|---|---|
| | Sustainable Chemistry |
| | Global Animal Health |
| | Road Transport Research Advisory Council (ERTRAC) |
| | Rail Research Advisory Council (ERRAC) |
| | Waterborne TP (supported by ACMARE, Advisory Council on Maritime R&D in Europe) |
| New technology based public goods or services with high entry barriers, uncertain profitability, but high economic and social potential | Mobile and Wireless Communications (eMobility) |
| | Innovative Medicines for Europe |
| Ensuring the development of the necessary technology breakthroughs to keep at the leading edge of technologies in high-technology sectors which have significant strategic and economic importance for Europe | Embedded Systems (ARTEMIS) |
| | Advisory Council for Aeronautics Research in Europe (ACARE) |
| | European Space Technology Platform (ESTP) |
| New technologies applied to traditional industrial sectors | Steel |
| | Future Textiles and Clothing (ETP-FTC) |
| | Manufuture - Future Manufacturing Technologies |
| | Construction Technology (ECTP) |

**Table 5**, The first twenty Technology Platforms launched in 2004

Source: (European Commission 2005c, 8)

Technology Platforms “are industry-led stakeholder fora that develop short to long-term research and innovation agendas and roadmaps for action at EU and national level to be supported by both private and public funding" (European Commission 2013e). Hence Technology Platforms can be conceived of as networking tools with which the EC attempts to mobilize and align industrial and other societal actors in specific technological sectors in order to exchange information and knowledge and to develop research agendas in common (European Commission 2013d, 2013e). The EC began to promote the concept of Technology Platforms in 2003 (European Commission 2005a, 5). By 2013 the number of existing Technology Platforms had increased to 38 (European Commission 2013b, 7, 8).

Technology Platforms are to play a key role in Horizon 2020. Their main function is to align diverse actors such as private enterprises, NGOs, the EU Member States, and research institutions in order to develop strategic research agendas and priorities which can then be implemented through other policy instruments such as "European Innovation Partnerships, European Industrial Initiatives, contractual and institutionalised public-private partnerships, Public-Public Partnerships (ERA-NETs, Article 185 initiatives, Joint Programming Initiatives), and the Knowledge and Innovation Communities of the European Institute of Innovation and Technology" (European Commission 2013b, 4). Hence the role of Technology Platforms remains a preparatory one. Technology Platforms do not receive any funding from the EC and they do not have any formal authority in the decisions on the funding of research projects (European Commission 2013b, 6).

These clarifications illustrate that the promotion of H & FC does not constitute an exceptional case but rather exemplifies the innovation turn in EU research policy after the Lisbon Council in March 2000. The Hydrogen and Fuel Cell Technology Platform is just one among twenty Technology Platforms that have been launched in 2004 which shows that H & FC constitute one of the key technologies which are promoted through the new R&I policy instruments of the EC. In addition, the concept of Technology Platforms reflects very well the main idea of innovation as promoted by the EC. For instance, Technology Platforms are to be industry-led which illustrates the increased focus on competitiveness that is to characterize EU R&I policy after the Lisbon Council. Furthermore, the ambition to mobilize and to align a wide range of different actors through Technology Platforms reflects the shift towards innovation policy which attempts to pursue a more holistic approach to science and technology development through the generation of innovation-stimulating frameworks. Thus the launch of the Hydrogen and Fuel Cell Technology Platform in FP 6 exemplifies very well the main ideas that dominated EU R&I policy in the first years of the new millennium.

A few years later the Hydrogen and Fuel Cell Technology Platform and four other Technology Platforms were chosen to be converted into Joint Technology Initiatives in the Cooperation Specific Programme of the seventh Framework Programme from 2007 – 2013:

| **Joint Technology Platforms** | **Budget (in € million)** | | |
|---|---|---|---|
| | European Community | Member States | Private Sector |
| Innovative Medicines Initiative (IMI) | 1 000 | 0 | 1 000 |
| Embedded Computing Systems (ARTEMIS) | 400 | 700 | 1 600 |
| Aeronautics and Air Transport (Clean Sky) | 800 | 0 | 800 |
| Nanoelectronics Technologies 2020 (ENIAC) | 450 | 800 | 1 700 |
| ***Fuel Cells and Hydrogen Initiative (FHC)*** | 470 | 0 | 470 |

**Table 6**, The five Joint Technology Platforms launched in Framework Programme 7

Source: (European Commission 2007c, 4, 2012a) (JTI Sherpas' Group 2010, 27–31)

The five Joint Technology Initiatives launched in FP 7 were designed as legal entities in order to mobilize large-scale public and private investments in research areas in which the Technology Platforms of the sixth FP could not provide the necessary means (European Commission 2007c, 4). All Joint Technology Initiatives had in common that there were one or more decision-making bodies, an Executive Director and staff, as well as internal or external advisory bodies (European Commission 2008b, 5). However, the concrete governance structure of each Joint Technology Initiative was kept flexible in order to be able to adapt to the specific technological challenges in each case (European Commission 2011c). Hence, in contrast to Technology Platforms, Joint Technology Initiatives constitute fully-fledged public-private partnerships equipped with their own budget and the authority to select and fund specific research projects. Joint Technology Initiatives "organise calls for proposals, oversee selection procedures and put in place contractual arrangements for projects set up to implement the JTI research agenda" (European Commission 2012a). The contribution of the EC to the first five Joint Technology Initiatives launched in 2008 ranges from € 0.4 – 1.0 billion as can be seen in the figure above (JTI Sherpas' Group 2010, 27–31).

The concept of Joint Technology Initiatives provides a prime example of how the EC attempts to implement its understanding of innovation in practice. The EC introduced Joint Technology Initiatives in its seventh FP "as a new way of realizing long-term public-private partnerships at European level" (European Commission 2007c, 4). Joint Technology Initiatives are supposed to present the first European public-private partnerships in research (JTI Sherpas' Group 2010, 2) and are to enable an effective implementation of research agendas and to support the development of technologies that are assessed as beneficial for the society (European Commission 2007c, 3, 2011c). The aim is to address "major issues by sharing pre-competitive knowledge, achieving critical mass, scale and scope in areas where global competitiveness is at stake, thus ensuring that the EU can lead the world in developing breakthrough technologies with high innovation potential" (JTI Sherpas' Group 2010, 2).

The financial contribution of the EC to the Joint Technology Initiatives stems from the Cooperation programme in FP 7 which promotes a broad range of alternative energy technologies among which H & FC.[7] The figure beneath provides an overview of the different programmes of FP 7 and the budget allocated to their implementation.

7 See http://cordis.europa.eu/fp7/energy/ for an overview of the energy technologies whose development is funded through the 7th Framework Programme. It should be noted, however, that the Framework Programme may not indicate all EU expenditures on the promotion of alternative energy technologies as it does not cover all EU R&I funding. Research projects can also be funded through the European Institute of Innovation and Technology that is not financed by the Framework Programm but rather out of the general EU budget.

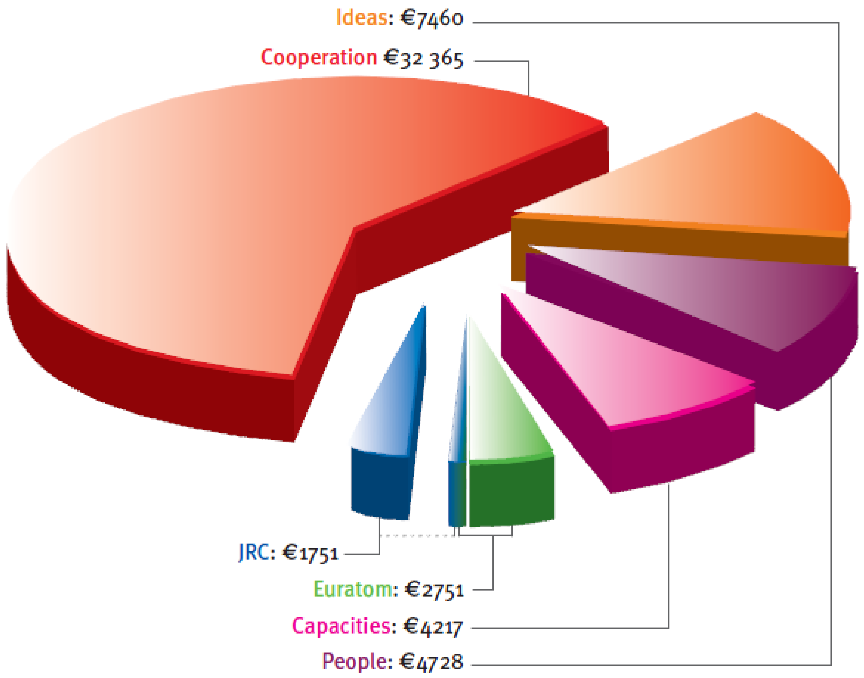



**Figure 8**, The indicative breakdown of FP 7 (in € million)

Source: European Commission, „FP7. Tomorrow's answers start today", 4.

Hence the promotion of H & FC by the EC constitutes a prime example of the new EU R&I policy in the era after the Lisbon Council in 2000. The development of H & FC has been funded by the usual means from FP 2 to FP 5 in the same way as the development of many other energy technologies. However, in FP 6 and FP 7 H & FC, together with a number of other technologies, have been declared as key technologies of the future which need to be promoted through specific R&I policy instruments. First, the EC dedicated one of the first twenty Technology Platforms that it launched in 2004 to the area of H & FC (European Commission 2005c, 8). Subsequently, one of the five Joint Technology Initiatives in the seventh FP was dedicated to H & FC (European Commission 2011e, 2). Therefore, both the Hydrogen and Fuel Cell Technology Platform and the Fuel Cells and Hydrogen Initiative provide prime examples of the innovation turn in EU research policy after the Lisbon Council

Furthermore, new research facilities in economically weaker European regions can be funded through the Structural Funds and the Cohesion Fund.

and the EC's attempts to implement its understanding of innovation. The following subchapter describes the development of a specific European H & FC policy after the Lisbon Council in more detail with a specific focus on the parallel development of policy and expertise.

## 4.4 The parallel development of EU H & FC policy and expertise in the years of 2002-2014

This subchapter illustrates the development of a specific EU policy for H & FC which began in 2002 and was accompanied by a parallel development of expertise on H & FC. Of course, the development of H & FC has been supported through EU research projects in several decades. However, before the launch of the Technology Platform for H & FC in 2004 most of these research projects were not related to each other and funded under different schemes as illustrated in the preceding subchapter. The table beneath provides an overview of the most important events in the simultaneous and interrelated development of EU H & FC policy and expertise.

| Theme / Year | Policy | Expertise |
|---|---|---|
| 2002 | The EC launches the **High Level Group** with the mandate to develop a vision for the future use of H & FC | |
| 2003 | | The High Level Group presents the vision: **Hydrogen Energy and Fuel Cells. A vision of our future** |
| 2004 | The EC launches the **Technology Platform** for H & FC | |
| 2005 | | The Technology Platform publishes the **Strategic Research Agenda** and the **Deployment Strategy** |
| 2006 | | |
| 2007 | The EC launches the project **FCHInStruct** which is to prepare the launch of a Joint Technology Initiative for H & FC | The Technology Platform publishes the **Implementation Plan**<br><br>The EC conducts an **Impact Assessment** for the launch of a Joint Technology Initiative for H & FC |
| 2008 | The Council of the European Union launches the Joint Technology Initiative for H & FC: **Fuel Cell and Hydrogen Joint Undertaking** | |
| 2009 | | The project FCHInStruct is completed by publishing a **Multi-Annual Implementation Plan** for the Fuel Cell and Hydrogen Joint Undertaking |
| 2010 | | |
| 2011 | | A **first interim evaluation** of the Fuel Cell and Hydrogen Joint Undertaking is conducted |
| 2012 | | |
| 2013 | The EC publishes a **Proposal for a Council Regulation** on the continuation of the Fuel Cell and Hydrogen Joint Undertaking | An **Impact Assessment** of the proposed continuation of the Fuel Cell and Hydrogen Joint Undertaking is conducted |
| 2014 | The Council of the European Union launches the **Fuel Cell and Hydrogen 2 Joint Undertaking** | |

**Table 7**, The parallel development of EU H & FC policy and expertise
Source: (author's own illustration)

As depicted in the table above the development of a specific EU H & FC policy began in 2002 as the EC decided to launch a High Level Group which was composed of nineteen representatives from scientific institutes, industry and public administration (High Level Group 2003, 5). The task of the High Level Group was to develop a common vision for the development of H & FC that all actors could identify with and that highlights the future potential of these technologies (European Commission 2002d). The High Level Group published a crucial report in 2003 in which it envisages the implementation of a European hydrogen economy by 2050 and recommends the launch of a European H & FC partnership in order to foster the development of these technologies (High Level Group 2003, 16, 23).

Based on these recommendations the EC launched the European Hydrogen and Fuel Cell Technology Platform (hereinafter HFP) in the scope of the sixth FP which in 2005 published the Strategic Research Agenda and the Deployment Strategy outlining how to commercialize H & FC (European Hydrogen & Fuel Cell Technology Platform 2005a, 2005b). The HFP encompassed a wide range of different actors as the attendance of its General Assembly by officials of the EC, representatives of EU Member States, officials of the German Federal Ministry for Economy and Labour, scientists of the German research institute Jülich, representatives of the automobile manufacturers BMW, Daimler, Honda, Renault, and Rolls-Royce, the energy providers BP, ExxonMobil, Shell, Sydkraft, and Vattenfall, the fuel cell manufacturer Ballard, and the producer of heating devices Vaillant indicates (European Hydrogen & Fuel Cell Technology Platform 2004a, 2004b). Hence both the High Level Group and the HFP have contributed to the development of a specific view on H & FC which different actors could align around. Simultaneously, the expertise developed affected the further course of EU H & FC policy.

On the basis of the expertise developed by the HFP, a Commission proposal, and the opinion of the European Parliament and the European Economic and Social Committee, the Council of the European Union set up the Fuel Cell and Hydrogen Joint Undertaking in 2008 which represents the legal entity of the public-private partnership Joint Technology Initiative on Fuel Cells and Hydrogen (Council of the European Union 2008, 1, 4; Fuel Cells and Hydrogen Joint Undertaking 2009, 4). In contrast to the HFP, the Fuel Cells and Hydrogen Joint Undertaking is equipped with its own budget of € 470 million. The task of the Fuel Cells and Hydrogen Joint Undertaking (hereinafter FCH JU) is to implement the European H & FC policy through the funding of projects that aim at the commercialization of these technologies.

The launch of the FCH JU was based on the development of further expertise on H & FC as the set up of Joint Technology Initiatives requires a formal impact assessment procedure. The main idea behind the Impact Assessments of the EC is to give decision-makers evidence on the advantages and disadvantages of a policy proposal. Impact Assessments are to explain "why action should be taken at EU level and why the proposed response is appropriate" (European Commission 2014f). Consequently, the launch of the Fuel Cells and Hydrogen Joint Undertaking was preceded by an Impact Assessment which the EC conducted in 2007 (European Commission 2007a). Hence the Impact Assessment for the FCH JU illustrates very well the parallel development of policy and expertise. Furthermore, it underlines the relevance of this thesis which investigates in how far this parallel development also was one of mutual influence that is to say in how far the development of policy and expertise not only took place at the same time but also affected each other.

For the preparation of the set up of the Fuel Cells and Hydrogen Joint Undertaking, the EC launched the project "Preparatory activities of the Joint Technology Initiative for fuel cells and hydrogen" (hereinafter FCHInStruct) which was led by industrial companies and funded by the EC under the seventh FP (European Commission 2012b). FCHInStruct was officially established on October 1st 2007 and ended by December 2008 (NEW Industry Grouping 2008, 9). The main objectives of the project were to further specify the governance processes of the FCH JU and to develop a concrete research, demonstration, and development agenda for H & FC which should be implemented by the FCH JU. Consequently, the actors involved in FCHInStruct published the Multi Annual

Implementation Plan in 2009 which, among others, defines the different technological areas of H & FC that are to be promoted by the FCH JU and distributes the available budget among these areas (Fuel Cells and Hydrogen Joint Undertaking 2009).

In addition to the preparation and the launch of the Joint Technology Initiatives, also their implementation and operation is intrinsically tied to the development of expertise as the EC commits itself to the conduct of interim and final evaluations of Joint Technology Initiatives (European Commission 2008c, 5). Indeed, the implementation and operation of the FCH JU was seized in a first interim evaluation in 2011 which was conducted by six experts who were appointed by the EC. This expert group analyzed all the documents on the FCH JU available to it and interviewed the key actors from the EC, the industrial companies and the public research institutes who were involved in the operation of the FCH JU. Finally, the expert group published the results of the evaluation in the First Interim Evaluation report (European Commission 2011d). This evaluation report included several recommendations on the improvement of the operation and the effectiveness of the FCH JU (European Commission 2011d, 4–6). Based on these results and suggestions for improvement, the FCH JU developed and adopted a revised Multi-Annual Implementation Plan in November 2011 (Fuel Cells and Hydrogen Joint Undertaking 2011c).

In 2012 and 2013 the preparations of Horizon 2020 which was to start in 2014 were under way and triggered the development of further expertise on H & FC as discussions on the continuation of the FCH JU arose. The EC conducted an online public consultation in order to seize the public opinion on the continuation of the FCH JU. Furthermore, the EC received diverse reports of interests groups arguing for a continuation of the FCH JU. In 2013 the EC published a proposal for a Council Regulation on the continuation of the FCH JU (European Commission 2013i) and an accompanying Impact Assessment (European Commission 2013a). Finally, in May 2014 the Council of the EU adopted the proposal and approved the continuation of a modified FCH JU in Horizon 2020 (Council of the European Union 2014).

In sum, the illustrations above should clarify the parallel and interrelated development of EU H & FC policy and expertise. EU H & FC policy relies on the provision of expertise. Simultaneously, expertise in the form of technology assessments and expectations triggers the application of policy instruments for the promotion of H & FC. Hence the central question is how the two processes of policy-making and expertise-making affect each other. How do for instance the political discussions that precede political decisions impact the development of expertise that occurs simultaneously? Likewise, one may wonder how the introduction of new findings on H & FC into the political discussion may strengthen certain political positions while weakening other ones. This thesis sheds light on these questions through an analysis of the co-production of EU & H & FC policy and expertise. For this purpose, the following chapter will explain the methodology that has been applied for this analysis and the empirical data that have been collected on the co-production of EU & H & FC policy and expertise.

# 5 Methodology and data sample

This chapter explains how the methodology and the methods of data collection applied in this thesis have been chosen on the basis of the insights of the preceding chapters which have outlined the research gap identified in the scholarly literature, explained the theoretical framework and the central research question of this thesis, and described the empirical case investigated. The stage of research in the scholarly literature has been outlined in chapter 2 which illustrated that both the Public Policy literature and the Science and Technology Studies have only paid little attention to the governance of EU R&I policy so far. The few studies that exist have largely neglected the role of science and technology in the governance of EU R&I policy. In addition, most of the studies remain on the theoretical level so that there are almost no empirical investigations of the Framework Programmes of the EC. Consequently, chapter 3 explained how this thesis is to contribute to filling this gap in research. For this purpose, an innovative theoretical framework drawing on both the Public Policy literature and the Science and Technology Studies has been developed. Based on this theoretical framework this thesis is to contribute to filling the gap in research through an analysis of the co-production of policy and expertise in the empirical case of the promotion of hydrogen and fuel cell technologies in the EU that was described in chapter 4. Hence the main objective of this thesis is to reach an in-depth understanding of the co-production of EU H & FC policy and expertise.

In order to achieve this objective the research design of an exploratory single case study has been chosen for this thesis. Exploratory case studies aim at exploring a specific phenomenon of which little is known so far. Therefore, due to the lack of previous studies of the role of expertise in the governance of EU R&I policy on which this thesis could build, an exploratory case study design is applied in order to shed light on the co-production of EU H & FC policy and expertise. The main objective is to reach an in-depth understanding of a specific process which is summed up by the central research question of this thesis: How are EU H & FC policy and expertise co-produced? In order to develop valid and reliable answers to this how question, different methods of qualitative data collection such as document analyses, semi-structured interviews, and direct observations have been applied in this thesis. The application of these three methods of data collection has been guided by the theoretical framework of this thesis and has been tailored to the empirical case of the co-production of EU H & FC policy and expertise in the years of 2000-2014. Hence data collection, analysis, and interpretation have been performed in parallel in an iterative process in order to increase the validity of the data sample underlying this thesis.

The following subchapters will explain the methodology applied in this thesis and the data collected in more detail. For this purpose, first the general features of an exploratory case study design are described. Thereafter, it is explained how the entry into the empirical field of the promotion of hydrogen and fuel cell technologies in the EU was prepared through document analyses which helped to identify the key persons working at the interface of the two discourses on policy and expertise. It is not only outlined how these persons were approached and asked for an interview but also what difficulties arose in this process and how they have been overcome. Finally, an overview of the data sample underlying this thesis is provided and it is explained how the data collected were analysed and interpreted.

## 5.1 Research design: The general features of exploratory case studies

The thesis at hand constitutes a single case study of the co-production of EU H & FC policy and expertise from 2000-2014. Of course, there are many types of case studies such as exploratory, descriptive or explanatory (Yin 1989, 59). This thesis is an exploratory case study as it aims at reaching an in-depth understanding of the co-production of EU H & FC policy and expertise. The main objective is to clarify the patterns of how policy and expertise are co-produced. Furthermore, there is only little research on the co-production of policy and expertise that this thesis could build on as has been demonstrated in subchapter 2.2. Thus an exploratory case study that examines the co-production of policy and expertise in general is needed before further studies can build on the results and highlight more specific aspects of this co-production.

However, conducting an exploratory case study does not mean to enter the field without any theoretical presuppositions. Rather, case study research often makes use of the concept of theoretical sampling which means the purposeful selection of data (Eisenhardt 1989, 537). In qualitative studies sampling does not need to ensure that all possible objects have the same chances to get into the sample. Instead the sampling should be theoretical and purposive in order to facilitate complete and accurate answers to the research question (White and Marsh 2006, 35–37). Therefore, data is collected according to its expected level of insight for the research question (Flick 1998, 65). Consequently, the theoretical categories presented in subchapter 3.4 such as discourse coalitions or the selection of experts have been developed in order to guide the collection of data in this thesis. Hence, data was gathered purposefully with the objective to shed light on the central research question and its subcategories.

In general, a single case study design allows data gathering from six different sources: documents, archival records, interviews, direct observation, participant observation, and physical artifacts (Baxter and Jack 2008, 554). The data collected for this thesis primarily stems from twenty semi-structured expert interviews which have been supplemented by document analyses. In addition, two direct observations have been performed. This triangulation is highly recommended in qualitative research as data gathering from multiple sources of evidence contributes to increased validity and reliability of the results of a study (Yin 1989, 95, 96). The methods of data collection applied in this thesis and the data collected will be described in more detail in the next subchapter.

Furthermore, as common in case studies, data collection and analysis were performed simultaneously and in parallel in this thesis (Eisenhardt 1989, 538, 539). Both were led by the theoretical propositions on the co-production of policy and expertise explained in subchapter 3.4. Simultaneous data collection and analysis denotes a reiterative process in which any data collected and analyzed informs the further data collection and analysis. This process has to be repeated until a theoretical saturation sets in which means that the collection of more data would not further elucidate the issue investigated (Eisenhardt 1989, 545). In this thesis data collection has been conducted until new interviews did not lead to any novel information but only reproduced the findings of previous interviews.

There are many techniques for the analysis of case study data such as for instance pattern matching, linking data to propositions, explanation building, time-series analysis, logic models, and cross-case synthesis (e.g. Baxter and Jack 2008, 554; Díaz Andrade 2009, 47). This thesis makes use of the technique of explanation-building that denotes a reiterative process which begins with an initial theoretical statement that is adjusted or refined through comparing it with the first empirical findings. This process has to be repeated until a conclusive explanation for the phenomenon at hand is reached in the form of a coherent narrative. Thus the technique of explanation-building will be applied in this thesis in order to develop a coherent explanation of the co-production of EU H & FC policy and expertise from 2002-2014.

Finally, it has to be elaborated whether and in how far the findings on the co-production of EU H & FC policy and expertise from 2002-2014 can be generalized to the broader area of EU R&I policy. In most case studies this is done through theoretical instead of statistical generalization which means that it has to be theoretically elaborated whether the explanation developed can be abstracted beyond the empirical case examined (Hamel, Dufour, and Fortin 1993, 48, 49). The main task is to detect those principles which regularly occur under specific circumstances, while sorting out aspects which are specific to the case in question (Gomm, Hammersley, and Foster 2000, 103). In this way it can be elaborated in how far the findings derived from the empirical case of EU H & FC policy and expertise might be representative for broader trends in EU R&I policy.

## 5.2 Approaching the field

The entry into the empirical field in this thesis began with thorough document analyses of the key text publications in the field of EU H & FC policy and expertise that were presented in subchapter 4.4. The figure beneath illustrates the interplay between these key documents and the policy instruments that were launched based on the expertise developed:

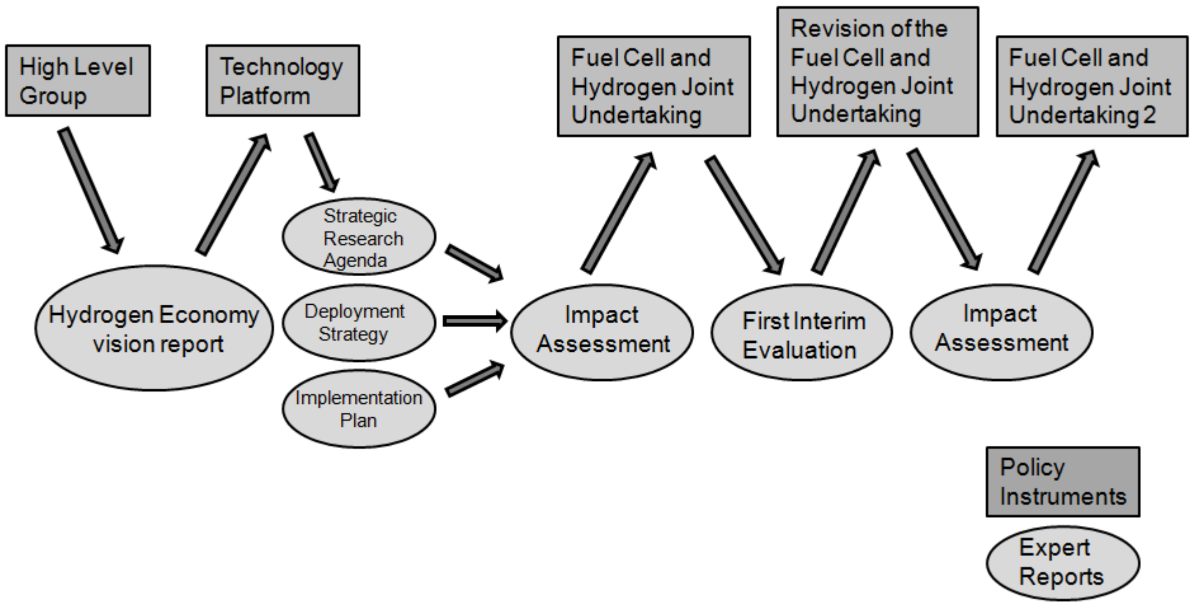



**Figure 9**, The parallel development of policy instruments and expert reports

(author's own illustration)

The document analyses of the official EC publications illustrated the eventual results of the co-production of EU H & FC policy and expertise, that is to say the policy and expertise that have been established in the end. However, in order to reveal the discussions that have led to this result and that thus constitute the actual processes of the co-production of policy and expertise, interviews with the persons involved had to be conducted. Both the expert reports and the policy instruments outlined in the figure above have been used to identify the key persons involved in the preparation of the documents and in the implementation of the policy instruments.

Hence the selection of the interviewees has been guided by the theoretical framework developed for this thesis. In order to shed light on the co-production of EU H & FC policy and expertise it has been attempted to interview persons that act at the interface of the two discourses on policy and expertise. Therefore, officials of the Directorate-Generals (hereinafter DG) R&I, ENER, and MOVE have been contacted as these are the DGs of the EC that take care of the implementation of the different policy instruments that have been launched for the promotion of H & FC. Thus these officials were not only involved in the expertise discourse on H & FC in which the different expert reports have been developed but also in the internal EC discussions on H & FC which were part of the policy discourse. In a similar vein it has been attempted to interview those representatives of private enterprises and public research institutes that have been involved in the compilation of the expert reports and in the political discussions on H & FC as these are the persons that act at the interface of policy and expertise. In contrast, the engineers and scientists who for instance work on the improvement of the membranes of fuel cells in the laboratories of the private enterprises and public research institutes have not been the primary focus in the data collection for this thesis as these persons, in most cases, have neither been involved in the compilation of the expert reports nor in the political discussions on H & FC. Thus the main focus in the data collection for this thesis was to interview those persons who acted at the interface of the two discourses on policy and expertise as mainly these would be able to provide the information needed to shed light on the central research question of the co-production of EU H & FC policy and expertise.

The document analyses of the expert reports and the publications of the EC in the area of hydrogen and fuel cell technologies have been conducted in order to identify the relevant persons acting at the interface of policy and expertise. Thereafter, these have been contacted via email with a request for an interview. Eventually, more than half of the persons initially contacted agreed to be interviewed and, even more important, many of these held or are holding key positions in the co-production of EU H & FC policy and expertise. However, based on different reasons several persons also refused to be interviewed. In addition to some persons who rejected the interview request due to a lack of time, several officials of the EC and Members of the European Parliament (hereinafter MEP) rejected the interview request on the basis that they are not involved in the development of H & FC any longer or that their involvement in the development of H & FC only constitutes a marginal part of their overall work. In fact, both reasons pointed to two more systematic issues in the promotion of H & FC in the EU as was revealed during the further course of data collection and data analysis. Therefore, the following paragraphs are to explain how these issues have been dealt with in more detail in order to avoid potential biases in the data sample and in order to ensure the validity of the data collected.

First, two MEPs rejected the interview request claiming that they were only marginally involved in the discussions of H & FC although they were members of the EP's Committee on Industry, Research, and Energy which compiled the statements of the EP on H & FC. However, one MEP of the group of The Greens/European Free Alliance did agree to be interviewed and this interview revealed that H & FC are only marginally discussed in the EP. Even in the case of the few MEPs that actually deal with H & FC, these technologies only constitute a marginal bit of their overall work. Hence the fact that only one MEP was interviewed for this thesis does not point to a systemic bias in the data collection but rather to one of the empirical research findings of this thesis which is that H & FC are only marginally discussed in the EP and that only a few MEPs are involved in these discussions.

Second, two officials of the EC rejected the interview request on the basis that they are not involved in the development of H & FC any longer. However, the interviews conducted with other officials of the EC revealed that the two officials who rejected the interview requests did not switch Units or DGs inside the EC and deal with issues other than H & FC but rather turned into critics of these technologies over time. Thus these two officials may not have been involved in the compilation of expert reports on H & FC or in the implementation of policy instruments for the promotion of H & FC any longer but they were still part of the policy discourse on H & FC as critics of these technologies. Hence the rejection of the interview requests by these two officials of the EC pointed to a potentially problematic bias in the data collection for this thesis. Internal critics of H & FC inside of the EC did not want to be interviewed for this thesis due to whatever reasons.

Consequently, different strategies have been applied in order to reduce and minimize this potential bias. All of the persons interviewed have for instance been asked what critique they face when they advocate H & FC to (other) officials of the EC. Based on the responses, further attempts have been made to conduct interviews with persons who are known for having a rather sceptical view of H & FC. Eventually, two interviews could be conducted with a MEP of the group of The Greens/European Free Alliance and with a representative of a NGO. Both persons have been involved in the policy discourse on H & FC and in the development of some of the expert reports outlined in Figure 9 and both had a rather critical view of H & FC. Furthermore, document analyses of scientific reports and newspaper articles have been conducted in order to identify critics of H & FC and their main arguments. These measures helped to reduce the bias in the data sample towards the proponents of H & FC and to provide a balanced account of the policy discourse on H & FC including the voices of the critics of these technologies.

In sum, the preceding paragraphs should outline how the empirical field of the promotion of hydrogen and fuel cell technologies in the EU was approached in this thesis. It was not only explained how the data collection was guided by the theoretical framework developed but also the difficulties encountered and the strategies applied for overcoming them have been illustrated. The main method for data collection were semi-structured interviews which were prepared by thorough document analyses of the expert reports and EC publications in the area of hydrogen and fuel cell technologies. Subsequently, the following subchapter describes the data collected and the analysis of this data in more detail.

## 5.3 The data sample and the analysis of the data collected

Altogether twenty semi-structured expert interviews have been conducted between November 2011 and February 2014. Of these altogether twenty interviews fifteen have been conducted face-to-face, four have been made via telephone, and one person preferred to answer written questions via email. Furthermore, fifteen of the twenty interviewees allowed recording the interview. The interviews recorded lasted between 22 minutes and two hours, with most of them being in a time range of 40 minutes to one hour and 30 minutes. Detailed notes were taken in all the interviews where recording was not permitted.

All of the twenty interviewees held key positions at the interface of the two discourses on policy and expertise at some point in time; either at the time when the interview was conducted or at some point in time before the conduct of the interview. In fact, the list of the persons interviewed comprises some of the key actors that were involved in the co-production of EU H & FC policy and expertise among which the Executive Director of the Fuel Cell and Hydrogen Joint Undertaking, a former Commissioner for Research, officials of the EC who were involved in the conduct of the Impact Assessments and the First Interim Evaluation and the experts that developed the expertise for these reports. Several persons involved have been interviewed for each policy instrument and expert report mentioned in Figure 9. This allowed me to gather diverse views on the launch and the implementation of policy instruments and on the development of expert reports which could be contrasted with each other in order to increase the validity of the data.

Individual interview guides have been prepared for each interview. These were more or less tailored to the interviewee in question depending on how much information was available on the professional background of that person. Some of the persons interviewed have been working in the area of H & FC for more than a decade with their name listed in several expert reports and policy instruments so that more specific questions on the direct involvement of these persons could be prepared. However, in other cases, only little information on the professional background of the interviewee was available so that the interview guide contained more general questions to first seize what projects the person has been working on so that more specific questions could be developed during the course of the interview.

In any case the course of the interview was not predetermined but rather the objective was to initiate a conversation in which the interviewee could explain his or her actions and experiences in detail. For this purpose, most of the questions were so-called open-ended questions which were applied deliberately to trigger longer responses instead of a simple "yes" or "no" or just a specific piece of information. The interviewees were asked to describe their roles and actions in the projects they were involved in. This allowed not only to reproduce who did what in specific projects but also to interpret the meaning that the interviewees saw in their actions. Furthermore, the answers of the interviewees could be compared to each other and cross-checked. The interviewer only intervened to adjust the course of the interview if it went off-topic.

In addition to the document analyses and the interviews, two direct observations were conducted at the Stakeholders' General Assembly of the Fuel Cell and Hydrogen Joint Undertaking on 22nd and 23rd November 2011 in Brussels and at the general assembly of the German public-private partnership for the promotion of H & FC, the National Organisation Hydrogen and Fuel Cell Technologies, on 7th and 8th November 2011. The Stakeholders' General Assembly is a two day conference held annually, with one day dedicated to the provision of a review of the research and demonstration projects funded by the FCH JU and the other day dedicated the provision of an outlook on envisaged activities of the FCH JU in the future. The event is open to all actors interested in the field of H & FC. Its main objective is to provide "a key platform for European and global stakeholders across sectors to come together to examine and assess the current position of this emerging industry, exchange ideas on next steps and make contacts" (Fuel Cells and Hydrogen Joint Undertaking 2011g). Also the general assembly of the German public-private partnership is a two day conference held annually, with one day dedicated to the provision of a review of the research and demonstration projects funded and the other day dedicated the provision of an outlook on envisaged activities.

The analysis of the interviews conducted began with transcription. The transcribed material was analyzed informally and interpreted with the theoretical framework presented in subchapter 3.5. In order to increase the validity of the data, the findings of the document analyses, the interviews, and the direct observations were not only cross-checked with each other but also triangulated through informal talks with experts on hydrogen and fuel cell technologies. In this way inconsistencies in the information collected could be resolved and inconsistent findings could be elaborated. Finally, the findings were organized chronologically and summarized into four main categories as will be explained in more detail in the following chapters. First, however, a few remarks on the anonymization of the identities of the interviewees have to be made in order to explain to the reader how the information collected through the interviews will be used to support specific interpretations in the following chapters that present the empirical findings of this thesis.

As agreed with the interviewees, their identities have been anonymized. Hence the list of the twenty interviewees (see Annex) does not include any names but only displays the date of the interview, the occupation of the interviewee and his or her involvement in different EU H & FC institutions. Of course, the occupation of several interviewees has changed during the course of data collection and some of the interviewees had already retired when they were interviewed for this thesis. Therefore, the list of interviewees only illustrates that occupation of each interviewee on the basis of which the interviewee has been selected for an interview, irrespective of whether he or she was still working in that occupation when the interview was conducted. Also the list of the involvement in different EU H & FC institutions for each interviewee is not exhaustive but rather indicates why this specific person has played a key role in the co-production of EU H & FC policy and expertise and thus was selected for an interview. Furthermore, both the occupations of the interviewees and their involvement in different EU H & FC institutions are described in rather general terms in the list of the interviewees in order to keep their identities as anonymous as possible. For this purpose, also the quotations of different interviewees in the following chapters 6-9 which present the empirical findings of this thesis do not refer to any names but only to the number assigned to the interviewee in question and to the year in which the interview was conducted.

These remarks on the anonymization should help the reader to understand the interpretations of the empirical data collected that will be presented in the following chapters 6-9. All the interpretations made and the conclusions drawn in the following chapters rely on the data collected through the interviews, the document analyses, and the direct observations; even if this may not be indicated with specific references in all cases. For heuristic purposes, the policy cycle model was applied to categorize the data collected into four different stages in the co-production of EU H & FC policy and expertise in the years of 2000-2014. Hence each of the following four chapters describes one stage in the co-production of EU H & FC policy and expertise and explains the specific characteristics that distinguish this stage from the other stages on the basis of the empirical data collected. In so doing, it is simultaneously illustrated that the categorization of the co-production of EU H & FC policy and expertise in the years of 2000-2014 into four different stages was not done in an arbitrary manner but rather through the interpretation of the empirical data underlying this thesis.

# Part III

# Empirical Analysis

# 6 2000 - 2004: Setting H & FC on the European agenda

This chapter explains the co-production of EU H & FC policy and expertise in the years of 2000-2004. For heuristic purposes this period of time can be categorized as the first stage in the co-production of EU H & FC policy and expertise in order to highlight the most important issues that have led to the launch of the Hydrogen and Fuel Cells Technology Platform in 2004 (European Commission 2002d) and the development of the vision of the hydrogen economy (High Level Group 2003). According to the empirical findings of this thesis, the co-production of EU H & FC policy and expertise in the years of 2000-2004 was most influenced by the stage of agenda-setting of the policy cycle model. Although, of course, different policy stages are present at any point in time and the co-production of EU H & FC policy and expertise in the years of 2000-2004 has in part also been influenced by the stages of policy formulation and decision-making, the empirical data analyzed for this thesis point out that the specific dynamics of the stage of agenda-setting have been the most prevalent ones in the co-production of EU H & FC policy and expertise in the years of 2000-2004.

Therefore, this chapter explains how this first stage in the co-production of EU H & FC policy and expertise in the years of 2000-2004 was shaped by the specific dynamics of the policy stage of agenda-setting in EU R&I policy. The Lisbon Council of March 2000 marked the beginning of a new European research and innovation agenda with the development of novel policy instruments such as Technology Platforms and Joint Technology Initiatives that should be applied for the promotion of key technologies of the future. Thus the new EU R&I policy in the first years of the new millennium was characterized by the identification and selection of the technologies that should be promoted by the new policy instruments. This required the development of expertise for raising attention for specific technologies by highlighting their potential for the achievement of the broader EU policy objectives such as competitiveness, economic growth, fighting climate change, etc.

Consequently, the proponents of H & FC developed the promising vision of a future European hydrogen economy highlighting the potential of H & FC for the achievement of EU climate, competitiveness, energy, research, and transport policy objectives. This vision was developed in the High Level Group which was launched by the EC in 2002 and which published in the report "Hydrogen Energy and Fuel Cells. A vision of our future" in 2003. The vision of the hydrogen economy was used by the proponents of H & FC to raise political attention for these technologies in order to make these technologies part of the new European research and innovation policy. As a result H & FC were selected as one of the technologies that should be promoted through the EC's new policy instruments in R&I and the EC launched the Hydrogen and Fuel Cells Technology Platform in 2004 (European Commission 2002d). Hence the general dynamics prevailing at the policy stage of agenda-setting guided the production of the expertise needed to make H & FC part of the new European research and innovation policy.

This co-production of EU H & FC policy and expertise that resulted in H & FC becoming part of the European innovation agenda is to be described in more detail in the following subchapters. First, it is outlined how this first stage in the co-production of EU H & FC policy and expertise was embedded in the specific dynamics of agenda-setting in the new EU R&I policy. Second, it will be described how the vision of the hydrogen economy was developed in the expertise discourse for the purpose of raising attention for H & FC by highlighting the potential of these technologies for the achievement of wider EU policy objectives. Third, it is outlined how this expertise on H & FC was fed into the policy discourse in order to gather further support for setting H & FC on the European political agenda. Finally, the main insights of this chapter are summed up.

## 6.1 The first stage in the new EU R&I policy: Setting the European innovation agenda

The co-production of EU H & FC policy and expertise in years of 2000-2004 was shaped by the general dynamics of the stage of agenda-setting in the new EU R&I policy. The Lisbon Council in March 2000 constituted the beginning of a new era of EU R&I policy as outlined in more detail in subchapter 2.1. New policy instruments such as Technology Platforms and Joint Technology Initiatives were to bring about European Research Areas. Hence this period in time was characterized by the EC's need to identify and to select the research areas and technologies that should be promoted by the novel policy instruments. This provided the proponents of specific technologies such as H & FC with the opportunity to make these part of the European innovation agenda. For this purpose, the proponents of a specific technology had to develop the expertise required to raise political attention to their case and to embed their favoured technology into the new EU R&I policy that is outlined in the following paragraphs.

The key aspects of the EU's Lisbon Strategy were competitiveness, innovation, and research which were perceived as the main drivers of economic growth and the creation of new jobs. Consequently, the main objective of the EU's Lisbon strategy was "*to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion"* (European Council 2000). Thus the Lisbon Strategy relied on a specific understanding of the relations between its key aspects of competitiveness, innovation, research, economic growth and the creation of new jobs. This understanding had been strongly influenced by the "systems of innovation" approach.

The following quotation exemplifies for instance how the EU follows the "systems of innovation" approach in recognizing that innovation cannot be achieved directly but only indirectly through the creation of innovation-friendly frameworks: "Specific action is also needed to encourage the key interfaces in innovation networks, i.e. interfaces between companies and financial markets, R&D and training institutions, advisory services and technological markets" (European Council 2000). This view on the interrelated nature of research, industry and market forces is further illustrated by the creation of the Competitiveness Council in June 2002 through merging the former Internal Market, Consumer Affairs and Tourism Council with the Research Council and the Industry Council. This should help the EU "to adopt a coordinated approach towards all these areas, which are vital for the competitiveness of the European economy" (Council of the European Union 2010).

Thus the dominant train of thought at that time was that innovation is the key factor for economic growth and an increased competitiveness of the European industry which would ultimately lead to the creation of new jobs. In other words, the key formula appears to have been: innovation = economic growth and jobs. Considering this immense importance ascribed to innovation, it does not come as a big surprise that everything perceived as a means for innovation received a significant boost as well. Hence a key role in achieving the knowledge-based economy was, among others, ascribed to research and development which should be fostered by "establishing a European Area of Research and Innovation" (European Council 2000).

Consequently, the Lisbon Council provided the momentum for the further development of a European research policy. Indeed the Lisbon Council endorsed the EC Communication "Towards a European Research Area" (European Commission 2000a) published only two months earlier. In this Communication the EC argued that the EU is losing track in research and technology development. Among others, the EC argues that the EU invests a smaller share of its Gross Domestic Product in R&D than the USA and Japan and that the gap between the total public and private expenditure on research of the EU and the USA is growing (European Commission 2000a, 4). Furthermore, the EC claims that the fragmentation of research into fifteen national research systems and the European FPs hinders the overall scientific productivity in the EU (European Commission 2000a, 7). To overcome these issues the EC argues for the establishment of a European Research Area which should integrate the different research systems into a coherent whole in order to increase the overall scientific output (European Commission 2000a, 7, 8).

The then Commissioner of Research, Philippe Busquin, seized this political momentum and set up an informal working group which was to elaborate the establishment of a high-level advisory body for science, technology and innovation in the EU (European Commission 2001e). Based on the recommendations of this working group, the EC established the

European Research Advisory Board in June 2001 (European Commission 2001a). The main task of this new Committee was to advise the EC in questions of research and technological development with a particular focus on the realization of the European Research Area and the use of policy instruments in the field of research (European Commission 2001a).

To sum up, the Lisbon Strategy and its underlying understanding of the relation between competitiveness, innovation, research, economic growth and the creation of new jobs provided the foundations for a new EU R&I policy in the first years of the new millennium. This provided the proponents of specific technologies with the opportunity to make these technologies part of the European innovation agenda. For this purpose, they had to raise the attention of European policy-makers to their favoured technology by highlighting how this specific technology can contribute to the achievement of the Lisbon Strategy. The following subchapters will explain how this was performed in the case of H & FC. First, subchapter 6.2 illustrates how different actors developed the expertise required to raise political attention for H & FC. Thereafter, subchapter 6.3 outlines how this expertise was used in the policy discourse to gather further support for H & FC.

## 6.2 The expertise discourse on H & FC: Highlighting the potential of H & FC for achieving wider EU policy objectives

Based on the empirical data analyzed for this thesis, this subchapter explains how a wide range of different actors produced the expertise required for raising political attention for H & FC. For this purpose, they developed the vision of the hydrogen economy which highlights the potential of H & FC for achieving wider EU policy objectives. Thus the production of expertise on H & FC was framed by the policy stage of agenda-setting which did not require a concrete H & FC development programme but rather a general vision highlighting the future potential of these technologies in order to raise political attention for them. The development of the vision of the hydrogen economy was driven by specific policy entrepreneurs who were equipped with the necessary resources to weave links between the political macro-level and the expertise discourse on H & FC. These policy entrepreneurs not only guided the production of expertise but also transferred it into the policy discourse where they used it to set H & FC on the European agenda as will be illustrated in subchapter 6.3.

To begin with, however, the following paragraphs are to explain development of the vision of a hydrogen economy in more detail. First, the emergence of the expertise discourse on H & FC with all the different actors involved in it will be described. Second, it will be outlined how the production of expertise was guided by the political objective to raise attention for H & FC. Third, it will be illustrated how the story line of the hydrogen economy was embedded in the broader policy objectives of the EU in order to raise attention for H & FC.

### 6.2.1 The emergence of an expertise discourse on H & FC

This subchapter is to outline the European expertise discourse on H & FC and the actors driving it in order to provide the reader with a better understanding of how H & FC were set on the European agenda. EU H & FC policy was not launched out of a vacuum in the first years of the new millennium but rather there was an expertise discourse on H & FC including many different actors that closely followed the policy discourses in the EU. This expertise discourse was driven by various actors such as policy-makers, scientists, and representatives of private enterprises that were involved in EU H & FC projects funded under different schemes of the past FPs in the 1980s and 1990s.

The following paragraphs will briefly describe the emergence of the expertise discourse on H & FC and the different actors involved in it. First, the European expertise discourse will be outlined. Second, it is highlighted that there also was an important national expertise discourse on H & FC in Germany led by the same actors that also played an important role in the European expertise discourse. Thereafter, the most important actors in the development of H & FC and their role in promoting H & FC will be outlined in more detail. These actors are the officials of the EC, the scientists of the Joint Research Centre of the EC, the scientists of public research institutes and universities, and the representatives of private companies.

*The European expertise discourse on H & FC*

As already explained in more detail in subchapter 4.2 and 4.3, the EC had been funding H & FC projects through its FPs since 1986. But apart from the technical progress and the political awareness that resulted from the projects funded, another important issue that has to be mentioned is the actual network or research infrastructure that emerged. The main point is that before an official EU H & FC policy was announced, there was an expertise discourse on H & FC driven by public research institutions, representatives of private enterprises and officials of different DGs of the EC.

Many important actors in contemporary EU H & FC programmes such as, for example, the private enterprises Intelligent Energy, Air Liquide and Daimler, the national research institutions Forschungszentrum Jülich and Commissariat de l'Energie Atomique, and the consultancy Ludwig-Bölkow-Systemtechnik have already participated in the European H & FC research and demonstration projects in the period of 1999-2002 (European Commission 2003c). Hence there have been personal relations between policy-makers of the EC, scientists of public research institutions, and representatives of private enterprises that were established over several years and that resulted in common discussions of H & FC.

The “Clean Urban Transport for Europe” project (hereinafter CUTE) that took place from 2001-2005 constitutes a prime example of the H & FC network that existed before an actual EU H & FC policy came into being. With € 52 million of which € 18.5 million came from the EC, the CUTE project had the largest total budget in the area of H & FC at that time (European Commission 2003a). Altogether 27 fuel cell buses powered by hydrogen were tested in regular traffic by public transportation companies in nine European cities. The project demonstrated how a complete energy cycle from hydrogen production and distribution in many different ways to its application in fuel cell buses could look like under the actual conditions provided in different European cities (CUTE 2006, 14, 15).

A quick look at the industrial partners involved in CUTE shows that these are the main actors in contemporary EU H & FC policy as well: BP, Daimler, Vattenfall, Hydro and Shell (CUTE 2006, 104, 105). While companies such as Vattenfall and BP took care of the hydrogen infrastructure for the project, Evobus which is a wholly owned subsidiary of Daimler provided the 27 fuel cell buses. Furthermore, many public research institutes, private consultant companies and public transportation companies were involved in the actual operation of the buses, the collection of technical data from this operation, and the final evaluation of the project (CUTE 2006, 104, 105).

The CUTE project highlights very well a couple of things that affected and enabled the launch of an EU H & FC policy in 2002. First, there was a political awareness and a good knowledge of H & FC in different DGs of the EC which is illustrated by the fact of the many existing research and demonstration projects in the area of H & FC that were coordinated and evaluated by officials from different DGs. Second, a European research infrastructure in the area of H & FC has already been in place. There were, for example, car manufacturers that were developing H & FC vehicles, utility companies that were looking for efficient ways of hydrogen production, and public research institutes investigating new potential ways of hydrogen production and safety issues around the use of hydrogen. All of these actors had invested time and financial resources in developing facilities and expertise in specific areas of H & FC. Therefore, third, it can be assumed that many of them at least had an interest in maintaining, if not increasing, the level of funding provided by the EC for the area of H & FC.

Hence these illustrations show that there was a European expertise discourse on H & FC that was led by officials of the EC, representatives of the private sector and public research institutions already before an official EU H & FC policy was launched. The actors leading this expertise discourse, however, were not equally distributed across the Member States of the

EU but rather most of them were based in Germany where the development of a national H & FC policy had been initiated before H & FC were placed on the European agenda.

*The H & FC discourse in Germany*

The launch of an EU H & FC policy was preceded by the development of a national H & FC policy in Germany. In May 1998 the Transport Energy Strategy was launched by the Federal Government of Germany represented by the Federal Ministry of Transport, Building and Urban Affairs and the private enterprises ARAL, BMW, Daimler, MAN, RWE, Shell and Volkswagen (Transport Energy Strategy 2007, 3). Later on the Transport Energy Strategy (hereinafter TES) was joined by Ford, GM/Opel, Total and Vattenfall (Transport Energy Strategy 2007, 5). The objective of the actors of the TES was to develop a strategy that should secure an international leading position for Germany in the field of alternative energies and their production and application in the transport sector during the next ten years (Transport Energy Strategy 2007, 3).

Based on the analyses of ten potential alternative fuels for a future sustainable transport system, the actors of the TES finally identified hydrogen produced from renewable energies as the most promising option (Transport Energy Strategy 2007, 4, 2007, 7). The actors of the TES decided to initiate national and European demonstration projects to illustrate the suitability for daily use of H & FC. Consequently, they launched the Clean Energy Partnership in October 2003 (Clean Energy Partnership 2007, 3), which is the largest national demonstration project for H & FC in the EU and which is funded by the Federal Ministry of Transport, Building and Urban with up to € 5 million (Clean Energy Partnership 2007, 12).

While the Transport Energy Strategy was dominated by private enterprises, there have also been institutions which included representatives of the public research institutes and policy-makers. In 2001 for instance actors from industry and science brought BERTA into being with the participation of the Federal Ministry of Economics and Labour. BERTA was a working group with the task of positioning the fuel cell technology in the Investing into the Future Programme of the Federal Government. Two years later, in 2003, the Federal Ministries of Economics and Labour, of Transport, Building and Urban Affairs, as well as of Environment, Nature Conservation and Nuclear Safety launched the Hydrogen Strategy Council. This Council was comprised of experts from industry and science as well as of representatives of Federal and State Ministries in order to coordinate the national activities in the field of hydrogen technologies (Marz 2010, 48–50).

These illustrations show there that has been a network of scientists, policy-makers and representatives of private enterprises in Germany that not only pursued H & FC projects and lobbied for H & FC in Germany but also attempted to extend its activities onto the European level. Indeed, these different actors maintained close relations and discussed the opportunities of a European H & FC policy first at the national level in order to align their views on H & FC before they presented these views at the European level.

*The officials of the EC*

In the case of H & FC the most important DG since the launch of an EU H & FC policy is DG Research & Innovation (hereinafter DG R&I). It is mostly the policy and scientific officers of DG R&I who have coordinated the H & FC research and demonstration projects funded by the EC between 1999 and 2002 (European Commission 2003c). As the funding of H & FC projects was dispersed over different funding programmes and schemes under the FPs, policy and scientific officers from different Units and Directorates within DG R&I were in charge of coordinating them. Apart from DG R&I also many policy and scientific officers from different Units and Directorates of the then DG Transport and Energy8 (hereinafter DG TREN) were involved in the coordination of the H & FC research and demonstration projects.

8 DG Transport and Energy existed until 2010 when it was split into DG ENER and DG MOVE.

Due to their involvement into these H & FC projects, these policy and scientific officers had most of the technical knowledge on H & FC inside of the EC.

The role of the policy and scientific officers is, however, not only to coordinate projects and to accumulate technical knowledge through these but also to transfer the most important aspects of this knowledge further up in the hierarchy of the EC. For example, on the intermediate level in the hierarchy of the EC are the Heads of Units and the Directors. The policy and scientific officers are directly subordinate to their Heads of Units so that there is a regular contact and exchange of information between these two levels. However, the further up it gets in the hierarchy the less people are actually involved in the projects funded and the more they are involved in strategic decisions and political discussions. Hence it is the task of the Directors to transfer the most relevant technical knowledge and the results achieved in the H & FC projects funded to the Directorate-Generals and the Commissioners. In this way the Heads of Units and Directors bridge different hierarchical levels in the EC from the policy and scientific officers in the units to the Directorate-Generals and the Commissioners.

Consequently, the different hierarchical levels of the EC are involved in the expertise discourse on H & FC to different extents. As already indicated above, there are no clear-cut boundaries between the discourses on policy and expertise but rather the overlappings between these different areas are characterized by blurred boundaries. Hence many actors of the EC are involved in both the expertise discourse and the policy discourse but to different extents. While the policy and scientific officers are more closely involved in the expertise discourse, the Commissioners of the EC are almost exclusively active in the policy discourse, and the Heads of Units, Directors, and Directorate-Generals bridge the gap between those two endings of the hierarchical scale.

*The Joint Research Centre of the EC*

Another important actor of the expertise discourse on H & FC was the Joint Research Centre (hereinafter JRC) of the EC. In fact, different Units and Directorates of the JRC have been involved in the expertise discourse on H & FC such as the Institute for Prospective Studies in Seville in Spain or the Institute for Environment and Sustainability in Ispra in Italy. The following paragraphs, however, will focus on the role of the JRC site in Petten in the Netherlands in order to provide an in-depth description of the involvement of the scientists of the JRC in the expertise discourse on H & FC.

The Institute for Advanced Materials (nowadays the Institute for Energy and Transport) of the JRC of the EC in Petten in the Netherlands has been dealing with hydrogen-related issues before the year 2000. However, hydrogen itself was not the main focus of the institutes' research activities but rather the scientists had experiences with hydrogen in research on preventing environment assisted cracking where small quantities of hydrogen can cause embrittlement in metallic materials. Still, this implied that the scientists of the JRC in Petten had gathered a lot of expertise on hydrogen over several years.

This fact became important around the turn of the century when the institute was to experience a major change in its focus of research. The new focus should be on energy research reflecting the EC's general ambition to develop an EU energy policy that the institute was to support with analyses and expertise. Consequently, the Institute for Advanced Materials was renamed into the Institute for Energy in 2001 (Joint Research Centre 2014a). Due to this change in its focus of research, the institute had to re-confirm its role as the in-house science service of the EC and to position itself anew as an advisory body in the field of energy research.

Against this background the scientists at the Institute for Energy started to discuss the chances to build up an EU H & FC research area with each other and with external actors such as car manufacturers. The idea of an EU H & FC research area opened up the opportunity to establish the Institute for Energy as the leading scientific institution in H & FC research. There were many scientists at the Institute for Energy who already had acquired a certain expertise in the field of H & FC during many research projects. However, due to the

EC's ambition to develop an EU climate and energy policy and the institutes' need to adjust its focus of research, the scientists of the Institute for Energy began to develop new expertise on H & FC with regard to the potential role of these technologies in a future emission-free energy and transport system.

*Public research institutes and universities*

The example of the Institute for Energy of the JRC illustrates several general features that have characterized the behaviour of scientists at other public research institutions, too. First, any research institution has to position itself somewhere in the overall scientific landscape. It not only has to decide what field of research it wants to focus on but also whether it wants to pursue research aiming at the fundamental understanding of certain issues or more use-oriented research or a combination of the two. These decisions are not least influenced by its source of funding.

There are far too many potential models of funding of public research institutes and universities to provide an exhaustive overview at this point. However, some general elaborations that often apply can be made. For instance, to maintain a certain source of funding or to increase the amount received, it might be needed to present a genuine research agenda that is not pursued by any other institute. Hence many public research institutes or universities find themselves pressured to identify a yet empty niche for themselves in the overall research landscape in order to acquire a specific research profile by which they can distinguish themselves from the rest.

Another important issue is whether most of the funding of a research institute comes from public or from private sources. Throughout the industrialized world there has been a trend in recent years towards decreasing the general budget that public research institutes and universities receive from their respective government in order to push them towards acquiring funding from other sources. A popular term in this respect was the one of the entrepreneurial university that has a comparably low amount of a fixed budget so that it has to acquire an increasing amount of its budget on its own through convincing potential donators that it is pursuing projects that are worth of funding.

This general trend has also affected public research institutes and universities in the field of H & FC. The Centre for Solar Energy and Hydrogen Research (hereinafter ZSW) in the German city of Ulm for instance was one of many research institutes that the German Federal State of Baden-Württemberg launched in the 1990s. In the first years after its launch, the ZSW received 100% of its budget from the Federal State of Baden-Württemberg. However, over the years this share was continuously decreased to 15-20% of the budget deliberately pushing the ZSW to acquire other sources of funding which has also changed its way of doing research as this quotation of a retired scientist of the ZSW illustrates:

> “you cannot do that by publishing an article in a journal but only by projects … you cannot continue to chase the decrease of absorption energy but you have to bring the product onto a new level” (Interviewee 1, 2011)

This shows the change that the ZSW was experiencing through being pushed to acquire more funding from the private sector. Its purpose of doing research changed from reaching a fundamental understanding of certain issues to improving the performance of specific technologies. The ZSW had to develop closer contacts to industrial companies under the conditions of the industrial partners as these were to provide the financial resources for the projects.

Hence the example of the ZSW illustrates how the way of doing research of public research institutes and their strategic positioning of themselves in the overall scientific landscape is affected by the relation of their amount of basic funding granted to the amount of funding that they have to acquire from other sources. The more public research institutes are relying on finding third sources of funding, the more they will seek cooperation with the private sector and adapt their way and focus of research to the needs and demands of the private sector. Furthermore, they will be looking out for opportunities to increase the overall amount of funding dedicated to their area of research.

Consequently, many public research institutes and universities involved in the development of H & FC had an interest in increasing the overall amount of funding dedicated to this area. Apart from the Institute for Energy of the JRC and the German ZSW, there were the French Commissariat de l'Énergie Atomique (hereinafter CEA), the German Jülich Research Centre (Forschungszentrum Jülich), the Italian National Agency for New Technologies, Energy and the Environment (hereinafter ENEA), the Energy Research Centre of the Netherlands (hereinafter ECN), and the Finnish VTT Technical Research Centre to name just a few examples. These institutions, and many others, were in contact with each other and tried to speak with one voice in order to increase their political weight in lobbying for H & FC.

*The private sector*

There has been a wide range of different companies that were involved in the expertise discourse on H & FC spanning large industrial companies such as Daimler and Air Liquide, oil companies such as BP and Shell but also small and medium sized enterprises in the form of H & FC equipment manufacturers such as Haldor Topsoe A/S or Solvay SA and in the form of consultancies such as Ludwig-Bölkow-Systemtechnik GmbH. All of these have been involved in the development of H & FC on the basis of different reasons and different interests as will be outlined in the following paragraphs.

The automotive sector has been most determined in promoting H & FC. This development was in part a response to the new emission regulations that have been tightened in many countries such as for instance in the USA and in particular in the State of California but also in the EU. While the regulations at the time being could still be met by incremental improvements of conventional cars with an internal combustion engine, the car manufacturers realized that they would have to develop zero emission vehicles in the longer run. Fuel cell vehicles powered by hydrogen offered the opportunity of sustainable mobility without emissions.

The main actor from the automotive sector has been Daimler that could build on its longstanding experience as it began to work on the development of fuel cell vehicles in the 1980s and had a close cooperation with the Canadian fuel cell manufacturer Ballard. Daimler had also made comparably high investments in coordinating large demonstration projects such as CUTE and in providing the fuel cell buses for these projects. However, not only Daimler but also Rolls Royce, Renault, Peugeot, and BMW have been active in promoting H & FC. To all of the car manufacturers H & FC constituted a potential opportunity to maintain their business of selling cars in a future hydrogen economy in the long term.

Apart from the automotive sector, other large companies involved in the development of H & FC have been oil companies such as BP and Shell, utility providers such as Vattenfall, and chemical producing companies such as Air Liquide and Linde. These companies had already been involved in the development of H & FC in several years and had very clear ideas about their potential roles in a future hydrogen economy. H & FC were part of their alternative technologies portfolio and they described themselves as future hydrogen producers or suppliers.

There have also been some small and medium sized companies that were involved in the development of H & FC such as fuel cell and fuel cell equipment or hydrogen equipment manufacturers. Although the resources that these companies could spend on promoting H & FC might have been limited compared to that of the large enterprises, their mere involvement constituted an important factor as small and medium sized companies were ascribed a key role in the development of innovations. In the EC's understanding of innovation small companies were seen as those who are more prone to accept the risks that accompany the development of radical innovations which is why they were assumed to play a key role in introducing and developing technological novelties in a specific sector.

Consultancies have constituted a further type of companies involved in the development of H & FC. The most important of these consultancies has been Ludwig-Bölkow-Systemtechnik GmbH (hereinafter LBST) that is based in Germany. LBST was founded in 1980 and developed over the 1980s and the 1990s to one of the world's most renowned consultancies in the field of H & FC. It has been involved in many H & FC research and demonstration projects funded by the Federal Government of Germany or the EC and it has advised many actors on the potential of H & FC. Through the involvement in these projects, LBST has developed good contacts to the large companies in the H & FC sector and to the officials of the EC as well as to the scientists of the JRC. They have conducted many analyses of the potential of H & FC and have been an important supplier of expertise to many actors in the H & FC sector.

Thus all of these different actors have been involved in the expertise discourse on H & FC and promoted these technologies. However, their influence on the development of expertise on H & FC varied considerably due to the different amount of resources in form of time and financial means available to them as will be illustrated in the following subchapter.

### 6.2.2 Developing expertise for raising attention for H & FC: The High Level Group

The development of expertise on H & FC was characterized by the broader dynamics of the stage of agenda-setting in policy-making. That is to say, expertise in the form of specific information on H & FC was developed for the purpose of raising political attention and support for H & FC. This affected the development of expertise in the sense that it enabled the different stakeholders to agree upon a common way to promote H & FC in spite of their different and partly diverging views of these technologies. The stage of agenda-setting did not require a sophisticated programme for the development of H & FC but rather a general vision outlining the importance of these technologies. Hence there was no need to assess the relative importance of the different H & FC technologies preferred but rather all technologies discussed could be promoted to emphasize the wide range of potential H & FC applications.

However, that does not mean that all actors involved had the same influence on the development of expertise but rather the general constellations in the two discourses as described in the previous two subchapters provided favourable conditions for a specific set of actors to assume leading positions in the co-production of EU H & FC policy and expertise. This set of actors included the then Commissioner for Research, Philippe Busquin, the president of the Foundation on Economic Trends, Jeremy Rifkin, and the representatives of large companies such as car manufacturers and energy utilities. Although many more actors were involved in the co-production of EU H & FC policy and expertise, these policy entrepreneurs played a key role and influenced the overall process more than others. Furthermore, it was these actors who most actively transferred the expertise developed into the policy discourse as will be illustrated in subchapter 6.3.

First, however, the following paragraphs are to explain how the High Level Group (hereinafter HLG) on H & FC was set up and how it compiled its final report. The main point is that the development of expertise in the HLG was driven by the policy entrepreneurs who had the resources to act at the interface between the two discourses and who ensured that the expertise produced is embedded in the broader policy objectives of the EC.

*The set-up of the High Level Group*

One of the most important actors in setting H & FC on the European agenda was the then Commissioner for Research Philippe Busquin. Busquin was eager to expand the cooperation in research and innovation of the EU with Japan and the USA. At his visits to the research ministries of these countries he saw that these were preparing national H & FC programmes and that H & FC were regarded as key technologies of the future. Analogous to Japan and the USA Busquin attempted to develop a European programme for H & FC and linked these technologies to the idea of a European research area. This key role of Philippe Busquin in setting H & FC on the European agenda is supported by the data collected from several interviews conducted for this thesis (Interviewee 4, 2011; Interviewee 8, 2012; Interviewee 19, 2012).

Consequently, the EC launched the High Level Group (hereinafter HLG) in 2002 against the background of similar advisory bodies in the USA and in Japan. The main task of the HLG was to gather the most important stakeholders and to increase the political awareness of H & FC. For this purpose it should work out how H & FC could fit into the overall European political agenda in order to illustrate how and why the EU should support the development of H & FC. Therefore, the HLG maintained close relations to the policy and scientific officers of DG R&I and held regular meetings with the Commissioner for Research Philippe Busquin. The HLG was also very well embedded in the expertise discourse and although it only comprised a few actors of the overall expertise discourse the development of the vision of a hydrogen economy was carried out in cooperation with the rest of the expert community.

While the decision to launch the HLG was made at the top of the EC by Romano Prodi, Loyola de Palacio and Philippe Busquin, the policy and scientific officers of DG R&I carried out its implementation which included the selection of its members. This selection relied on the EC's general criteria for the selection of experts according to which the composition of the HLG was to include private and public representatives from all sectors with an interest at stake in H & FC and to represent the EU geographically. In addition, the EC is to ensure an appropriate gender balance in its expert groups (European Commission 2010c, 10, 11). However, given the *de facto* non-existence of women in the field of H & FC at that time the establishment of a gender-balanced expert group was a rather hopeless endeavour. In the end, all of the experts selected were men.

The criterion of the appropriate representation of all sectors with an interest at stake was applied according to the view of H & FC as an emerging industrial sector that will develop technologies enabling an emission-free energy and transport system in the future. Consequently, the HLG was composed of very different actors such as large car manufacturers, energy utilities, public transport enterprises, SMEs such as fuel cell manufacturers and fuel cell equipment manufacturers, and public research institutes. The criterion of a geographical representation of the EU explains why the members of the HLG came from many different EU Member States although the most active organizations engaged in the development of H & FC were based in Germany.

The policy and scientific officers of DG R&I did not select the experts themselves but rather invited organizations to participate in the HLG. The organizations selected decided on their own whom they would delegate to the HLG. Most of the nineteen organizations chosen for the HLG were industrial enterprises such as car manufacturers and oil companies (High Level Group 2003, 32, 33). However, there were also a few representatives of public research institutes and national research agencies. An assistant accompanied each of the nineteen representatives delegated to the HLG from his/her organization. These assistants were called SHERPAs and they were supposed to accomplish all the more practical work such as writing the final report. However, while the assistants actually wrote the final report, the general work of the HLG and thus the development of the vision of the hydrogen economy were mainly driven by specific policy entrepreneurs as will be outlined in the following paragraphs.

*The development of the story line of the hydrogen economy*

While many different actors were involved in the development of the story line of the hydrogen economy, the most influential ones were the policy entrepreneurs that ensured that the expertise produced is embedded in the broader policy objectives of the EC. These were, above all, the then Commissioner for Research, Philippe Busquin, and the representatives of the large car manufacturers and energy utilities. Most of the latter were based in Germany and not only knew each other from national H & FC programmes but also had the clear and determined objective of bringing H & FC onto the European political agenda. Their agreement upon hydrogen as the most promising fuel for a future emission-free transport sector was based on the discussions and analyses conducted in the Transport Energy Strategy. This German H & FC network comprised several large companies among which the car manufacturers BMW and Daimler, the oil companies BP and Shell, the utility provider Vattenfall and the chemicals producing company Linde.

These actors dominated the regular meetings of the HLG which were held in Brussels and hosted and organized by the policy and scientific officers of DG R&I. At these meetings the potential areas of application for H & FC were discussed. While all members of the HLG shared the overall objective of setting H & FC on the political agenda of the EU, the diversity of the member organizations also implied different and in part diverging interests in specific technologies in the field of H & FC. These diverging interests should play an important role in the later stages of European H & FC policy. However, at this early stage there was no need to pursue particular interests to the fullest but rather it was necessary to demonstrate the overall commitment to H & FC by the actors involved in the expertise discourse. Although there have been controversial discussions on what specific technologies in the area of H & FC should be included in the final report, these did not lead to bigger conflicts as the task of the HLG was not to formulate a concrete research programme but rather a broader vision for the promotion of H & FC in general.

Consequently, the focus of the HLG was on reaching a broad agreement encompassing all views and not on discarding specific options. In fact, the wide range of different H & FC technologies was rather portrayed as an advantage by emphasizing the flexibility of H & FC. This flexibility meant that both hydrogen and fuel cells can be combined with a wide range of other technologies. Hydrogen could, for instance, be produced from a wide variety of different energy sources without releasing emissions into the atmosphere. This would not only allow switching gradually from hydrogen production from fossil energy sources to renewable ones but also suit the interests of the EU Member States with their very diverse domestic energy markets. While electricity production in France, for instance, predominantly relies on nuclear energy, Poland has a high share of coal in its energy sources for electricity production and Germany has a mix of fossil, nuclear and renewable energy sources.

However, hydrogen was not only flexible in its way of production but also in its application as it could be used in a wide range of different technologies. In the transport sector, for instance, hydrogen did not have to be used in fuel cells but could also be used as a fuel in internal combustion engines which would deliver the mechanical energy needed for vehicle propulsion. Hydrogen could also be added to other fuels such as methane that could be supplemented by 20-30% hydrogen without the need to adapt the engine. In a similar vein, the flexibility of fuel cells was highlighted. These could not only convert hydrogen into electricity but could also run on other fuels such as ethanol, methanol, biogas, natural gas, or gasoline. Fuel cells could convert any of these fuels into electricity and heat for residential and industrial buildings or provide electricity to applications of different sizes ranging from a mobile phone to an aircraft.

The following quotation of a retired representative of a car manufacturer who was a member of the High Level Group exemplifies very well the idea of the flexibility and the supplementary nature of different H & FC technologies:

> "The idea of the High Level Group was that the hydrogen economy, the idea is in fact technology related to H & FC is not only dedicated to one application. In fact you can imagine a lot of applications, very different, for example, Nokia is working on the mobile phone using a fuel cell, house, aircraft, trains, and so, lot of applications. But, in fact, the idea is H & FC change the world, change completely the way to produce and to use energy, is a new paradigm. You know, you had in the past oil paradigm, for example, or nuclear paradigm. Hydrogen is in fact changing completely the society, changing completely the organization of energy in the society." (Interviewee 2, 2012)

### 6.2.3 Embedding H & FC in the wider EU policy objectives: The story line of the hydrogen economy

This subchapter explains how the supporters of H & FC linked these technologies to the wider EU policy objectives in order to raise political attention for setting H & FC on the agenda. The figure below outlines the vision of the hydrogen economy that was developed by the HLG:

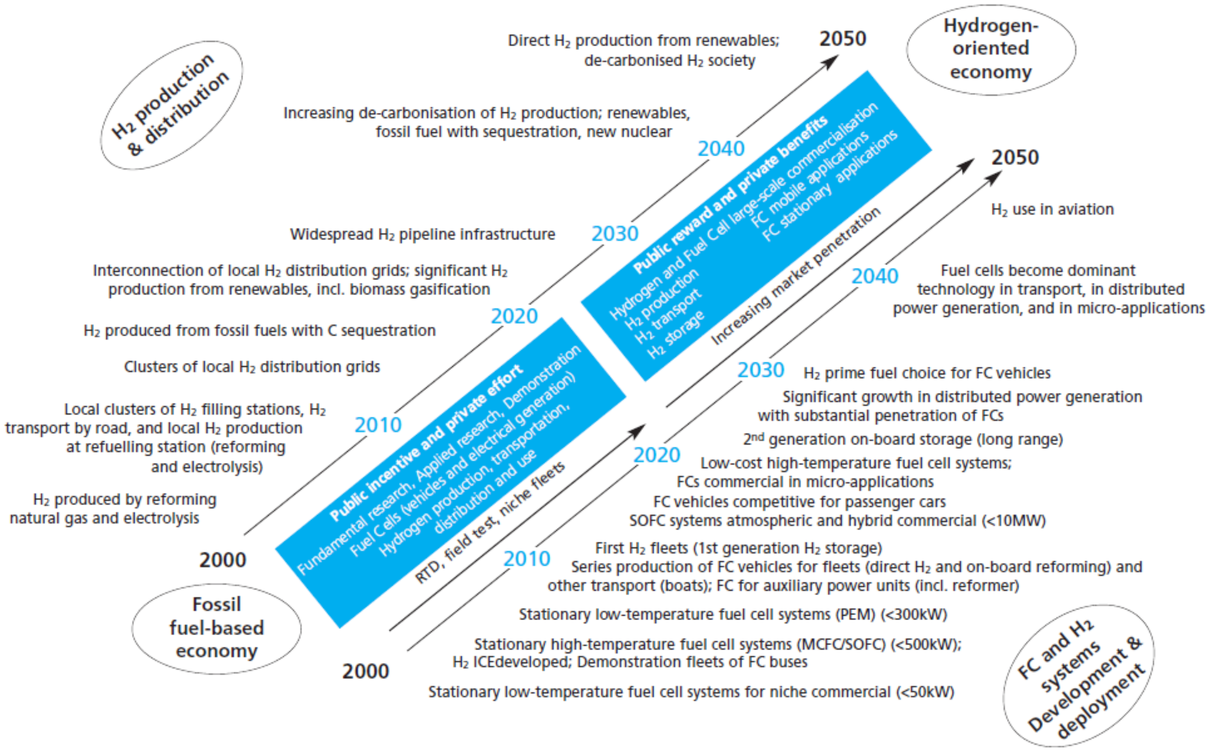



**Figure 10**, The European vision of a hydrogen economy

Source: (High Level Group 2003, 23)

The figure above illustrates that the main idea was to move from the present economy that is based on fossil fuels to the hydrogen economy until 2050. The hydrogen economy was a vision of a fully decarbonized, emission-free society. Hence hydrogen should be produced from renewable energy sources and used in fuel cells. In fact, any electricity needed should come from fuel cells powered by hydrogen. Fuel cells should generate electricity in vehicles, private households and industrial buildings, as well as in micro applications such as laptops and mobile phones.

This vision of a hydrogen economy should be implemented step by step over the coming decades until 2050. First, local clusters of hydrogen filling stations should be built and hydrogen should be produced from a variety of sources such as fossil fuels with $CO_2$ sequestration, nuclear energy and renewable energies. Over the years the hydrogen infrastructure should be further built up with distribution grids and pipelines and hydrogen production from renewable energy sources should steadily increase until all hydrogen would be produced from renewable energy sources by 2050. In parallel, fuel cell applications should first be promoted through niche markets and demonstration projects so that their share in electricity production continually increases until 2050.

The development of this vision of a hydrogen economy was guided by specific policy entrepreneurs in order to raise political attention for H & FC as outlined in subchapter 6.2.2. For this purpose, H & FC were linked to the developments on the political macro-level and portrayed as the ideal means to achieve the objectives of EU competitiveness, research and innovation policy, EU climate and energy policy, and EU transport policy. The following paragraphs are to illustrate how H & FC were to contribute to the achievement of these objectives according to the story line of the hydrogen economy. First, it will be outlined how H & FC were linked the main objectives of the Lisbon Strategy with its focus on innovation and competitiveness. Second, it will be explained how the proponents of H & FC portrayed these technologies as the ideal means for fighting climate change and for achieving an emission-free energy system. Third, it will be illustrated how H & FC were promoted as the key technologies for the establishment of an emission-free transport system which is the main objective of European transport policy.

*A European H & FC research area for innovation and competitiveness*

The following paragraphs are to illustrate how the proponents of H & FC embedded these technologies into the general objectives of the Lisbon Strategy and how the development of national H & FC policies in Japan and in the USA helped them in their argumentation. The Lisbon Strategy with its focus on innovation and competitiveness dominated the European political agenda around the turn of the millennium. Both innovation and competitiveness were seen as the driving forces of economic growth and the creation of new jobs by the EC. The supporters of H & FC attempted to embed these technologies into this line of thinking by portraying them as key technologies of the future that would increase the competitiveness of the European industry and lead to the creation of new jobs. This competitiveness was outlined as being endangered as other countries such as the USA and Japan were leading the development in H & FC while the EU was lagging behind.

The storyline of the hydrogen economy was very skilfully woven into the innovation frame with its focus on competitiveness and economic growth. H & FC were promoted as key technologies of the future that would create economic growth and new jobs in the EU. It was argued that the development of H & FC would strengthen the European industry and open up export opportunities for alternative energy and automotive technologies. To reach these benefits, however, the EU had to compete with countries such as the USA and Japan which were spearheading the development. In fact, several large industrial companies, above all the car manufacturers based in the EU, argued that the EU is lagging behind in the development of H & FC and that it must intensify its efforts if it wants to compete with the USA and Japan.

Indeed, the development of a European H & FC policy was preceded by similar developments in the USA and in Japan. In the USA, the National Energy Policy Development Group, established by the then US president G. W. Bush and composed of high-ranking US-politicians, authored in 2001 the National Energy Policy Report (National Energy Policy Development Group 2001, vi, viii) in which H & FC are presented as promising technologies of the future. Based on these hopes and expectations the “National Hydrogen Vision

Meeting" was convened in Washington in 2001. More than 40 representatives from energy companies, environmental organizations and US Federal and State authorities came together with the specific objective to develop a common vision of a future hydrogen economy and to identify its timeframe and the necessary steps towards its realization (US Department of Energy 2001, iii). They published the results of their discussion in the report "A National Vision of America's Transition to a Hydrogen Economy – To 2030 and Beyond" (US Department of Energy 2002a). Thereafter the "National Hydrogen Energy Roadmap Workshop" was convened where again high-ranking representatives from politics and industry gathered in April 2002 (US Department of Energy 2002b, 3).

A similar development took place in Japan around the same time. The Agency of Natural Resources and Energy of Japan's Ministry of Economy, Trade and Industry created the committee "Policy Study Group for Fuel Cell Commercialization" which should serve as an advisory body for its Director General in 1999 (Hachisu 2005, 2; Maeda 2003, 12). This Committee was comprised of 28 representatives from research institutions and public and private enterprises (Maeda 2003, 13). In 2001 the committee submitted two reports, the "Study Group Report on Commercialization of Fuel Cell Technology" and "PEFC & Hydrogen Energy Technology Development Strategy", to the Director General of the Agency of Natural Resources and Energy (Maeda 2003, 14). These two reports provided a roadmap with timeframes for the commercialization of fuel cells (Maeda 2003, 11). Japan's Ministry of Economy, Trade and Industry launched the consortium "Fuel Cell Commercialization Conference of Japan" on the basis of the recommendations from the committee in 2001. This consortium consisted of 134 private companies and individuals and was supposed to coordinate the commercialization of fuel cells and to influence government policies (Hachisu 2005, 2; Maeda 2003, 15, 16).

The supporters of H & FC used these developments in Japan and in the USA to underpin their view of the endangered competitiveness of the European industry. In fact, this argument was often underpinned by very concrete numbers illustrating the higher efforts of the USA and Japan in financial terms and the future economic value of H & FC. In its final report the

HLG stated that the US administration had proposed to invest $ 1.7 billion in H & FC development over the next five years page. This proposed US support for H & FC was to be around five to six times higher than the anticipated EU support under FP 6. These investments might contribute to the creation of 750,000 new jobs until 2030 according to the US Department of Energy (High Level Group 2003, 15). Also the policy development in Japan was taken into account. It was argued that Japan had dedicated an estimated $ 240 million to H & FC development in 2002 and that Japan had targets of 50,000 fuel cell vehicles sold by 2010 and 5 million by 2020 (High Level Group 2003, 15).

Another important aspect of the Lisbon Strategy was the European research area. Above all the then Commissioner for Research, Philippe Busquin, and the officials of DG R&I argued for the establishment of a European H & FC research area and underpinned this with their expertise on the funding of H & FC under the FPs. Their main argument was that H & FC funding is low, fragmented and uncoordinated. H & FC were portrayed as a range of different technologies that have been funded separately by the EC so that a unified European approach for the development of these technologies would not only bring about more coordination but also synergies between the different projects. Furthermore, it was argued that a supportive European policy framework would be needed to handle the risks and to facilitate the high investments required of industrial actors and investors. Therefore, the EU needs to develop a coherent and supportive policy framework in order to improve the overall coordination and to achieve the critical mass in funding needed.

In sum, H & FC were portrayed as innovative energy technologies that can increase the competitiveness of the European industry and contribute to economic growth and the creation of new jobs in the future.

*EU climate and energy policy: H & FC for an emission-free energy system*

The following paragraphs are first to outline the development of EU climate and energy policy in more detail before it is illustrated how H & FC were presented as the ideal means to achieve the key objectives of these policies. The EU began to introduce different measures to reduce GHG emissions in order to fight climate change in the 1980s. Since then there has been a constant introduction of new measures and a regular tightening of existing ones. Some of these measures aim at reducing the average GHG emissions from different types of vehicles. For this purpose, the EC negotiates the maximum emission limits together with the car manufacturers. In addition to EU climate policy, the EC attempted to lay the foundation for a European energy policy in the 1990s. This energy policy should focus on three main objectives: 1) ensuring the competitiveness of the energy market, 2) securing the supply of energy, and 3) developing a more ecological energy system.

In May 2002 the EU ratified the Kyoto Protocol which was adopted at the United Nations Climate Change Conference in Japan in 1997 (European Commission 2002e). By ratifying the Kyoto Protocol the EU committed itself to reducing its greenhouse gas emissions to 8% below the levels in 1990 by 2008-2012. As a first step the EC launched the European Climate Change Programme in June 2000 which was “to identify and develop all the necessary elements of an EU strategy to implement the Kyoto Protocol” (European Commission 2014c). The EU Emissions Trading System launched in 2005 is for instance one of the most important initiatives that have resulted from the European Climate Change Programme (European Commission 2014d).

In order to reduce the emissions caused by the transport sector, the EU had introduced its first emission standards for large goods vehicles in the 1980s. These were further refined, tightened, and expanded to other types of vehicles in the 1990s. Also around the turn of the century the EC discussed the further development and implementation of its emission standards for different types of vehicles such as passenger cars, light commercial vehicles, and large goods vehicles. In June 2000, for instance, the EP and the Council of the EU adopted a proposal of the EC to set up a monitoring scheme for the average specific emissions of $CO_2$ from new passenger cars (Council of the European Union 2000).

In contrast to these emission reduction measures, the EU did not have a dedicated energy or transport policy around the year 2000. However, it was at that time that the EC tried to lay the foundations which should allow for the development of these policies later on. In 1995 and 1996 the EC published the Green Paper “For a European energy policy” and the White Paper “Energy policy for Europe” in which it defines the security of supply, environmental protection and competitiveness as the primary objectives of European energy policy (Pollak, Schubert, and Slominski 2010, 85). Subsequently, the EC expressed its ambition to increase the share of renewable energy sources to 12% by 2010 in the Green Paper “Energy for the future: Renewable energy sources” in 1996 and the White Paper “Towards a common strategy and a(n) action plan: Energy for the future: Renewable energy carriers” in 1997 (Pollak, Schubert, and Slominski 2010, 85). In the year 2000 the EC published further Communications emphasizing the importance of energy efficiency, environmental protection and the development of a European energy market, before in 2002 and 2003 these objectives were confirmed once more in the chapter on energy of the European constitution (Pollak, Schubert, and Slominski 2010, 86–89).

In order to raise political attention to H & FC the proponents of these technologies argued that H & FC constitute the ideal means to achieve EU climate and energy policy objectives. H & FC were supposed to contribute to fighting climate change by reducing emissions in the energy and transport system. Hydrogen was presented as a clean energy carrier that can be produced in many different ways and from many different sources without generating $CO_2$ emissions. It was argued that nuclear energy, renewable energy sources and even fossil energy sources together with carbon capture and sequestration could be used to produce hydrogen without to release any dangerous emissions into the atmosphere. This flexibility was highlighted as a very positive aspect as it allowed adapting hydrogen production to the different local conditions prevalent throughout the EU.

H & FC were also highlighted as the main components of a more ecological energy system. Hydrogen powered fuel cells could not only be used for vehicle propulsion but also to provide electricity for basically any device that needs it without causing any emissions.

Indeed, fuel cells could provide electricity to any products from portable devices such as mobile phones and laptops to mobile applications such as cars, buses, and ships, to stationary applications in the domestic and industrial sector. In addition, fuel cells could also be used as auxiliary power units or stationary back-up devices in remote regions or in locations where uninterrupted electricity supply is of utmost importance such as, for instance, in hospitals. In all of these different cases, fuel cells could convert hydrogen into electricity without generating emissions.

Furthermore, it was argued, that fuel cells would contribute to both the security of energy supply and a more ecological energy system through the high efficiency of fuel cells in converting hydrogen into electricity. Fuel cells were seen as a means to reduce energy consumption due to their efficiency. This efficiency was to be particularly high in stationary applications as fuel cells could not only provide electricity to residential and commercial buildings but also supply these with heat at the same time in combined heat and power systems. Hence the main argument was that fuel cells could contribute to a lower overall energy consumption which both would be more ecological and increase the security of supply.

H & FC were also to enable a decentralized energy system in which electricity could be produced close to where it was to be consumed. This was to make local electricity supply less dependent on the overall grid and thus further increase the security of supply. Hydrogen could be used as a storage medium for renewable energies that could be converted into electricity through fuel cells whenever needed. This would provide for an emission-free energy cycle from hydrogen production to electricity consumption and increase the stability of the electricity grid.

These arguments were often underpinned by very concrete numbers and comparisons to highlight the potential of H & FC for achieving the EU's climate policy objectives as this quotation from the report of the HLG exemplifies: "Together, 15% regenerative hydrogen vehicles and the above distributed fuel cell/gas turbine hybrid systems could deliver about 250 Mt $CO_2$ savings per year. This is approximately 6% of the energy-related $CO_2$ emissions forecast in 2030, and progress such as this would allow Europe to move beyond the Kyoto Protocol" (High Level Group 2003, 14).

In sum, H & FC were portrayed as the ideal means to fight climate change and to achieve the three key objectives in EU energy policy which are to ensure the competitiveness of the energy market, to secure the supply of energy, and to develop a more ecological energy system.

*EU transport policy: H & FC for decoupling the transport sector's dependence on oil*

The following paragraphs are first to outline the foundations for the development of a European transport policy that were laid in the early 1990s before it is explained how the proponents of H & FC attempted to link these technologies to the objectives of EU transport policy. The main objective of the emerging European transport policy was the development of a more ecological transport system. For this reason the EC began to identify what alternative fuels and drivetrain technologies could contribute to a more sustainable transport sector in the future and how these could be promoted.

In 1992 the EC published its Green Paper "The impact of Transport on the Environment. A Community strategy for sustainable mobility" (European Commission 1992). Around the turn of the century the EC made further efforts in the development of a European transport policy. In its White Paper "European transport policy for 2010: time to decide" in 2001 the EC proposed 60 measures to improve the transport sector in the EU spanning a wide range of issues from passenger rights to infrastructure challenges that might result from the enlargement of the EU in 2003 (European Commission 2001g). In the same year the EC proposed a Council Directive in which it argues for the establishment of an obligatory minimum share of biofuels in the overall transport fuels sold in each Member State from 2005 onwards (European Commission 2001b).

The EC publications in the fields of energy and transport policy illustrate that H & FC have already been considered in both areas as environmentally benign options in the longer term before there was an official EU H & FC policy. In the EC's Green Paper "Towards a European strategy for the security of energy supply" fuel cells are mentioned as an option for decentralized electricity production (European Commission 2001c, 31). Hydrogen, together with biofuels and natural gas, is seen as a clean fuel that could be used to power fuel cell vehicles in the longer term (European Commission 2001c, 44, 70, 71). Also in the EC's White Paper "European transport policy for 2010: time to decide" and in its Proposal for a "Council Directive on the promotion of the use of biofuels for transport" H & FC are seen as promising options for a cleaner transport system in the long term (European Commission 2001d, 3, 2001g, 86–88).

In contrast to hydrogen, the EC discarded the chances of the related battery technology to play an important role in a future transport system (European Commission 2001b, 10, 11). In the early 1990s the battery electric vehicle was perceived by many people all over the world as the most promising technology to replace conventional automobiles. Consequently, large demonstration projects and implementation programmes were launched in many countries (Fogelberg 2000, 1). However, many of these projects showed that the battery technology still faces a lot of technical challenges and thus the envisaged large-scale commercialization did not materialize. The EC for instance attested in its Proposal in 2001 that the big size and the high price of batteries as well as the slow recharging and the limited power and range of battery electric vehicles hampers these from appealing to many consumers (European Commission 2001b, 10). Therefore, "the Commission sees little prospect in maintaining the electric car on the list of candidates for high-volume marketable alternative vehicles (European Commission 2001b, 11).

Hence H & FC did not step out of nowhere on the European agenda in the first years of the new millennium but rather different DGs of the EC had already developed quite a clear idea of the potential areas of application of these technologies in the future. Furthermore, the related battery technology was not perceived as very promising at the time around the year

2000. In other words, while one of the two technologies that principally could contribute to zero emission vehicles in the long term was discarded as an option at the beginning of the new century, the other technology had a network of proponents in diverse DGs of the EC.

These promoted H & FC as the ideal means to establish an emission-free mobility. It was argued that the most efficient way of using hydrogen in the transport system would be fuel cells which could convert hydrogen into electricity that would move the vehicle without generating any emissions in the entire process from hydrogen production to vehicle propulsion. Fuel cells that run on hydrogen could be used to power cars, lorries, buses or ships and thus offered the opportunity of maintaining the current standard of mobility without its negative consequences such as GHG emissions. In this way H & FC were linked to the discussions on emission limits per car fleet in the EU. The introduction of fuel cell vehicles fuelled by hydrogen was supposed to reduce the average $CO_2$ emissions per km for new vehicles sold. Hydrogen powered fuel cell vehicles do not cause any emissions and would thus improve the local air quality. Furthermore, these vehicles cause considerably less noise than conventional cars with an internal combustion engine. Hence H & FC would not only contribute to fighting climate change but also to a healthier local environment in terms of noise and pollution.

Introducing hydrogen into the transport sector was also perceived as contributing to the three main objectives of the EU's energy policy: 1) security of energy supply, 2) an environmentally benign energy system, and 3) a competitive energy market. The fact that hydrogen can be produced from different energy sources such as nuclear, fossil, and renewable ones was promoted as an opportunity to decouple the transport sector's dependence on oil. While electricity already was produced from a wide range of different energy sources in the EU, the transport system relied almost exclusively on gasoline and diesel that are both produced from crude oil. Thus hydrogen was promoted as an alternative to oil-based fuels and as a means to increase the security of energy supply by reducing the EU's dependence on the import of oil. Hydrogen could be produced from domestic energy sources such as solar or wind power and offered the chance to get renewable energies into the transport sector. Against the background of rising oil prices, the scarcity of oil, and the political instability of oil-producing countries, decreasing the EU's dependence on the import of oil was perceived as a key issue in increasing the security of energy supply and hydrogen was portrayed as the ideal means to achieve this.

Above all the automotive sector stressed the need of H & FC for fighting climate change due to the transport system's dependence on oil. The two major fuels used in the EU are gasoline and diesel that both are produced from crude oil so that both cause emissions when burned in the internal combustion engine of a vehicle. Hence it was argued that emissions in the transport system could only be fully avoided by substituting gasoline and diesel with a clean fuel. Hydrogen was presented as the ideal fuel as it could be produced from a variety of sources such as renewable energies, nuclear energy, and fossil energy with CCS without to cause any emissions. After production it could be used to power a fuel cell vehicle without to cause any emissions except of water vapour or it could be used in a vehicle with an internal combustion engine which would at least not cause any $CO_2$ emissions.

This argumentation benefitted from the EC's view on the battery technology at the time being. While in principle, both hydrogen in fuel cells and electricity in batteries could be used to power vehicles without to cause any emissions, many large-scale demonstration projects for battery electric vehicles in the 1990s have not led to the desired technological and commercial breakthrough. As a consequence, a certain disappointment spread out and the battery technology was not perceived as a viable means to achieve a sustainable transport system in the long-term in the early 2000s. This left hydrogen as the only fuel available to achieve a fully emission-free transport system in the long term which helped the proponents of H & FC to raise attention to these technologies and to gather further support for them in the policy discourse as will be illustrated in the next subchapter.

## 6.3 The policy discourse: Raising attention for the hydrogen economy

# Chapter 6 2000 – 2004: Setting H & FC on the European agenda

This chapter explains how attention was raised to the hydrogen economy in the policy discourse which resulted in the policy output of the launch of the Hydrogen and Fuel Cell Technology Platform. First, the discourse coalition supporting the story line of the hydrogen economy is illustrated. It is not only outlined what actors supported the story line of the hydrogen economy but also how this story line was transferred from the expertise discourse into the policy discourse. Above all the role of specific policy entrepreneurs such as Philippe Busquin, Jeremy Rifkin, and the representatives of large private enterprises in feeding the story line of the hydrogen economy into the policy discourse is highlighted. It is mainly these actors who linked the development of expertise on H & FC to the developments on the political macro-level and who then promoted the story line developed in the policy discourse.

Second, the discourse coalition criticizing hydrogen as inefficient and not ecological *per se* is illustrated. This discourse coalition emerged in response to the story line of the hydrogen economy and was above all supported by members of the European Green Party and environmental NGOs. These developed their own expertise highlighting critical aspects on H & FC that were not included in the story line of the hydrogen economy. Their main points of critique were that H & FC are only ecologically benign if hydrogen is produced from renewable energy sources and that hydrogen production in general is rather inefficient as a lot of energy is lost during the necessary processes of conversion.

Finally, the policy output of the policy discourse on H & FC is illustrated. In the end the opposition to the storyline of the hydrogen economy was marginal and could not prevent the many supporters of the story line to place H & FC on the agenda. This not only marked the beginning of a European H & FC policy but simultaneously also stabilized the expertise on H & FC developed in the expertise discourse on H & FC against the expertise put forward by the critics of H & FC. Thus setting H & FC on the European agenda constituted the last bit in the first stage of the co-production of EU H & FC policy and expertise resulting in the launch of the Hydrogen and Fuel Cells Technology Platform in 2004.

### 6.3.1 The discourse coalition supporting the story line of the hydrogen economy

The three most important supporters of the story line of the hydrogen economy were the then President of the EC, Romano Prodi, the then Commissioner for Research, Philippe Busquin, and the then Vice-President of the EC and Commissioner for Energy, Loyola de Palacio. In addition, H & FC had many proponents on different hierarchical levels in DG R&I and DG TREN. The story line of the hydrogen economy was also supported by some, individual Members of the EP belonging to different parties. However, H & FC were not debated much in the EP and both the number of proponents as well as the number of opponents was limited to a few individual Members of the EP. The following statements, made at the launch of the HLG, illustrate the support of the story line of the hydrogen economy of Romano Prodi, Loyola de Palacio, and Philippe Busquin:

> Romano Prodi: “This is an important choice for Europe. Hydrogen technology will not only reduce our energy dependency and GHG emissions; in the long run it will also change considerably our socio-economic model and create new opportunities for developing countries.”

> Loyola de Palacio: “"I am looking for new and original ways to reduce the European Union’s dependence on oil while at the same time contributing to sustainable development. Hydrogen and fuel cells offer such a possibility and they can contribute significantly to our policy objective of replacing 20% of automotive fuel with alternative fuels by 2020. In addition, hydrogen brings important opportunities for the distribution of sustainable energy (e.g. renewables) and for decentralised power generation.”

> Philippe Busquin: “To meet the stringent Kyoto Protocol targets, the EU will increase the use of renewable energy sources and substitute fuels – including hydrogen. Today, hydrogen and fuel cells are too expensive, that is why we need a consistent approach at a European level. By bringing industrialists, researchers, users and policy

> makers together, we aim to help build consensus and ensure Europe is leading the drive towards sustainable energy." (European Commission 2002d, 1)

These statements show that Romano Prodi, Loyola de Palacio, and Busquin had a clear idea of how H & FC would fit into the wider EU agenda. They associated H & FC with the objectives of EU climate policy, energy, innovation, and transport policy and sustainable development. However, in contrast to Philippe Busquin, Romano Prodi and Loyola de Palacio have not been involved in the expertise discourse on H & FC but rather the story line of the hydrogen economy was transferred to them by certain policy entrepreneurs equipped with the necessary resources to act in the interface between the two discourses on policy and expertise.

In fact, it was first of all large private enterprises such as car manufacturers, energy utilities, or oil companies that possess the resources which allow them a direct contact to the college of Commissioners. These large companies are not only of a high economic importance to the EU due to their large number of employees but also their cooperation is required for the implementation of many objectives in EU climate, energy, and transport policy such as for instance the reduction of GHG emissions. This granted the representatives of these companies a direct access to Romano Prodi, Loyola de Palacio, and Philippe Busquin so that they could articulate their support of the story line of the hydrogen economy at various personal meetings.

Many of these companies that played a key role in setting H & FC on the EU agenda were based in Germany as already outlined above. They had developed contacts to each other over several years through common H & FC projects on the national level and, in spite of pursuing different interests in H & FC, they promoted the general story line of the hydrogen economy emphasizing the importance of all H & FC technologies in common in order to place H & FC on the agenda in the first place. Their main argument was that the development of an EU H & FC sector would create economic growth and jobs in the EU. To accomplish this, however, there was supposed to be an urgent need of public funding in order to catch up with the Japanese and US H & FC sector which were leading the development. Above all the German car manufacturers argued that H & FC would be commercialized anyway, if not in Europe, then somewhere else. Therefore, it was important to build up an H & FC industry before it was built up in other countries so that not only new jobs would be created but also existing ones preserved as for instance the manufacturing of propulsion systems would shift from internal combustion engines to fuel cells.

These large companies from the German H & FC network had one big advantage over smaller companies or many public research institutes and that is an easier access to the hierarchical high-end of the EC. The Directors and CEOs of large companies often have direct access to the President or the Commissioners of the EC due to the economic importance of their companies and their large number of employees which enables them to directly present their view to the college of the Commissioners. In contrast, getting direct access to the Commissioners or to the higher ranking officials in the DGs proves to be much more difficult for the representatives of smaller companies as the following quotation of the retired CEO of a SME illustrates:

> "The Commission is always inclined to restrict the contacts to the higher levels which has to do with its typical view of its own hierarchy which is not overly conducive. The director or the CEO of a company is not necessarily a person to speak to for a director in the EC, in his view, except of if it concerns large companies." (Interviewee 3, 2011)

In addition, it was not only the representatives of these large private enterprises but also the then Commissioner for Research, Philippe Busquin, who played a key role in transferring the story line of the hydrogen economy from the expertise discourse into the policy discourse on H & FC. Philippe Busquin promoted H & FC as one of those technologies for which a European Research Area should be established. While also Romano Prodi and Loyola de Palacio were actively promoting H & FC in the policy discourse, they were not as active as Philippe Busquin in the interface between the two discourses. Philippe Busquin not only assumed a leading position in linking the development of expertise on H & FC to the objectives on the political macro-level but also actively transferred the story line of the hydrogen economy into the policy discourse.

Furthermore, Philippe Busquin, Romano Prodi, and Loyola de Palacio not only had various meetings with the representatives of the large private enterprises but also visited several universities and research institutes which performed research and demonstration projects on H & FC. At these visitations the Commissioners saw in practice how hydrogen was produced from renewable energies and how this hydrogen could be used to power boats and cars without generating emissions. In addition to the demonstration that H & FC applications actually work, these occasions provided the Commissioners with the opportunity to directly talk to researchers and scientists and to hear about their views on H & FC. These meetings also illustrated that there is a wide range of different actors interested in the development of H & FC and able to implement a European H & FC research area.

The general discussion on H & FC at that time also enabled individual actors to exert a certain influence on the political discussion. One of the most important policy entrepreneurs has been Jeremy Rifkin, the founder and president of the Foundation on Economic Trends. Rifkin wrote the book "The Hydrogen Economy" in which he envisages a completely transformed, decarbonized and decentralized energy system with hydrogen and fuel cell technologies at its heart (Rifkin 2003). He advised both Romano Prodi and Philippe Busquin who not only invited him to personal meetings but also to speak in the EP in order to raise further support for the story line of the hydrogen economy. Indeed, two of the interviews conducted (Interviewee 6, 2012; Interviewee 19, 2012) confirm that Jeremy Rifkin was one of the key advisers of the EC at that time, regarded as an expert with scientific authority by many actors in the EC. Thus his words in the promotion of H & FC weighed a lot.

In addition, the Commissioners observed the developments of national H & FC policies in the USA and in Japan and attempted to include the EU in this global development. In both countries expert groups and advisory bodies had been launched in order to gather all actors with an interest at stake to develop visions and roadmaps for the commercialization of H &

FC. On 25 June 2003 the then President of the EC, Romano Prodi, the then President of the European Council, Konstandinos Simitis, and the then President of the USA, George W. Bush issued a Joint Statement in Washington, DC, in which they declared “to collaborate on accelerating the development of the hydrogen economy” (Council of the European Union 2003).

In December 2003 the then Commissioner for Research, Philippe Busquin, visited Japan to participate in the meeting of the research ministers of the G8 countries and to promote scientific cooperation between Japan and the EU (EC 2003 Busquin visits Japan, 1). Shortly before his visit to Japan, the then Commissioner for Research, Philippe Busquin, said: “In cutting-edge and frontier technologies such as hydrogen and fuel cells, and nanotechnology, Japan is a world leader” (European Commission 2003b). In another EC press release from 2002 it is stated that the USA and Japan are world leaders in fuel cell research, while the “EU efforts in this field are not structured and they are under-funded and fragmented” (European Commission 2002d, 2).

Apart from the Commissioners, there were also many supporters of the story line of the hydrogen economy inside of the EC on different hierarchical levels in DG R&I and DG TREN. Heads of Units, Directors, and Directorate-Generals promoted H & FC actively and advocated the future potential of H & FC to their colleagues on the same hierarchical level. Thus there were many officials who actively promoted the story line of the hydrogen economy as also the following quotation of a scientific officer of the EC exemplifies: “For us the final report of the High Level Group was the bible, we believed in it” (Interviewee 4, 2011).

Hence there was a broad discourse coalition supporting the story line of the hydrogen economy comprising officials on all hierarchical levels of the EC including the President of the EC and the Commissioners for Energy and Research. These actors were supported by individual Members of the EP and by many different actors from the private and the public sector. In fact, while large private enterprises were able to promote H & FC more than other actors due to their strong resources, the existence of a wide range of different organizations including public research institutes and SMEs expressing an interest in the development of H & FC constituted a supportive factor in itself. The existence of this wide range of different actors not only fitted well into the EC's understanding of promoting innovation but also indicated that there is an emerging H & FC sector encompassing all actors needed for the development of the hydrogen economy from hydrogen producers and suppliers to fuel cell manufacturers.

### 6.3.2 The discourse coalition criticizing hydrogen as inefficient and not ecological *per se*

The critique on the hydrogen economy was a combination of the development of counter expertise on the efficiency of H & FC and the linkage of H & FC to the policy discourse on nuclear energy. The discourse coalition critical of H & FC argued that H & FC are neither efficient nor ecological *per se*. This discourse coalition was composed of Members of the European Parliament, who, above all, belonged to the Green Party, representatives of environmental Non-Government Organizations such as Greenpeace and the World-Wide Fund for Nature, and a few officials of the EC although the resistance inside of the EC was rather marginal. The discourse coalition was rather loosely composed of diverse critics of H & FC that were not in direct contact with each other but criticized H & FC in public for the same reasons. Their two main points of critique target the production of hydrogen as will be outlined in the following paragraphs.

The first main argument was that H & FC are inefficient because a lot of energy is lost during the production of hydrogen. The critics highlighted that hydrogen constitutes an energy carrier such as electricity or gasoline and as such is not available in its pure form in nature but rather has to be generated in a process that requires the input of primary energy sources such as wind power, solar power, nuclear power or crude oil. There are diverse pathways of hydrogen production which differ in efficiency such as electrolysis and reformation but the critics of H & FC assessed all of them as inefficient due to the high losses of energy in the conversion of primary energy sources into hydrogen. Instead they argued that in most cases it would be more efficient to convert the primary energy sources directly into electricity or mechanical energy and that hydrogen production would only make sense as a means for energy storage in the case of a surplus of electricity production from renewable energies.

Hence the discourse coalition based their critique of H & FC on their own expertise which they developed in response to the storyline of the hydrogen economy. The concrete technical data such as the efficiency rate of reforming natural gas into hydrogen compared to the efficiency rate of combusting natural gas directly were not developed by the discourse coalition itself but rather by research institutes that were not involved in the political discussions. Different critics of H & FC commissioned analyses and studies on diverse aspects of H & FC independently of each other from research institutes with which they maintained good relations and which they trusted.

The second main point of critique resulted from linking H & FC to the policy discourse on nuclear energy. The main critique was that the production of hydrogen was not supposed to be exclusively based on renewable energy sources but was to include nuclear energy as well. In fact, the critics of H & FC were not against H & FC *per se* but rather against nuclear energy which they saw as dangerous and not ecological. Hence their fear was that H & FC could be used to legitimize the use of nuclear energy and the construction of new nuclear power plants. Indeed, the promoters of H & FC such as the then Commissioner for Energy, Loyola de Palacio, and the then Commissioner for Research, Philippe Busquin, did not regard nuclear energy as problematic and thus saw hydrogen production from nuclear energy and the construction of new nuclear power plants as one among other opportunities.

Hence the vision of the hydrogen economy reproduced the existing lines of conflict of the discourse on nuclear energy that emerged in the 1970s. Indeed, hydrogen production from nuclear energy was an idea that the operators of nuclear power plants promoted in the 1970s and 1980s. In 1974 for instance the Hydrogen Economy Miami Energy Conference took place in Miami Beach, Florida, USA which led to the establishment of the International

Association for Hydrogen Energy later on in the same year (International association for hydrogen energy 2014). Among others, utility companies operating nuclear power plants were interested in the development of the hydrogen economy.

The main idea was to keep nuclear power plants working on a constantly high level throughout the year so that they constantly produce the same high amount of electricity. In times of a lower demand, the surplus of electricity could be used to generate hydrogen. From the point of view of nuclear power plant operators this was a tempting idea because once a nuclear power plant is built and in operation the actual costs of running it are comparably low so that higher electricity production increases the margins provided that all of the electricity can be used and sold.

Therefore, the discourse coalition critical of H & FC accused the nuclear energy industry of pursuing a hidden agenda by promoting the hydrogen economy in order to anchor and legitimize nuclear energy in the energy system.

### 6.3.3 Policy output: H & FC become part of the European innovation agenda

The main output of the European policy discourse on H & FC was the EC's decision to select H & FC as one among other technologies for the promotion through its new policy instruments in EU R&I. Consequently, the EC launched the Hydrogen and Fuel Cell Technology Platform in 2004 which not only marked the beginning of an EU H & FC policy but at the same time stabilized the expertise underlying the vision of a hydrogen economy and discarded the expertise developed by the critics of H & FC.

This policy output resulted from the strong support of H & FC of many actors in the EC and not least from the active support of Romano Prodi, Philippe Busquin, and Loyola de Palacio. There was a broad discourse coalition including many different actors such as large private enterprises, public research institutions, and SMEs in addition to the officials of the EC. In contrast, the discourse coalition arguing against H & FC was only supported by individual Members of the EC and the representatives of environmental NGOs. Consequently, the critique on H & FC was rather marginal compared to the broad-based support of it. In addition, the critics were equipped with fewer resources to promote their arguments and partly Romano Prodi, Philippe Busquin, and Loyola de Palacio did not share their factual critique as they did not regard hydrogen production from nuclear energy as problematic.

Finally, another important factor at that time was that there was no other technology that was regarded as viable for the achievement of a sustainable and emission-free transport system. The battery technology that in principle also could enable an emission-free transport system was discarded as a viable option at that time due to large demonstration projects that did not meet the technical expectations but rather revealed the technical problems that prevented the commercialization of the technology. This left H & FC as the only option that was regarded as promising for the establishment of a future emission-free mobility in the years around the turn of the millennium. While the EC also selected other technologies from, for example, the areas of pharmaceutics or aeronautics for the promotion through its new policy instruments in research and innovation, H & FC were the only technologies that were regarded as viable in the area of energy and transport. As a result of this, the opposition to H & FC in the EC was minimal and the critics did not have a viable technology which they could promote as a more efficient alternative to H & FC.

## 6.4 Conclusions

This chapter explained the co-production of EU H & FC policy and expertise in the period of time of 2000-2004 including the development of the vision of the hydrogen economy and the launch of the Hydrogen and Fuel Cell Technology Platform in 2004. This specific period of time was categorized as the first stage in the co-production of EU H & FC policy and expertise for heuristic purposes in order to highlight the most important issues that influenced the co-production of EU H & FC policy and expertise at that time. These were the specific dynamics of the stage of agenda-setting of the policy cycle model according to which agenda-setting is about raising political attention for a specific issue. Consequently, the proponents of H & FC produced the expertise required to raise attention to H & FC in order to make these technologies part of the new EU R&I policy that was initiated by the Lisbon Council in March 2000. Thus the vision of the hydrogen economy did not constitute a concrete research programme for H & FC but rather highlighted the future potential of these technologies for the achievement of broader EU policy objectives in order to raise political attention to H & FC.

In addition to these specific dynamics of the stage of agenda-setting in the new EU R&I policy, the second factor that had a strong impact on the co-production of EU H & FC policy and expertise were the resources available to the different actors promoting H & FC. Resources in the form of time, access to the decision-makers in the EC, and financial means enabled specific policy entrepreneurs to assume leading positions in the co-production of policy and expertise by linking these two discourses to each other. It was above all the then Commissioner for Research, Philippe Busquin, and the representatives of the large private enterprises such as car manufacturers, oil companies, and energy utilities who could assert their views on H & FC in the production of expertise on these technologies due to their high hierarchical positions in the EC and in the large private enterprises. In contrast, the representatives of smaller companies and public research institutes only played minor roles in the expertise discourse on H & FC. Hence, while the specific dynamics of the stage of agenda-setting influenced the role of expertise in the policy process, the resources available to the different actors determined what actors could assert their views on H & FC in the production of expertise.

In fact, the leading role of large private enterprises in the expertise discourse on H & FC was also supported by the specific understanding of innovation of many officials of the EC. In the Lisbon Agenda of the EC innovation was regarded as a key means to bring about economic growth and to increase the competitiveness of the European industry. Thus innovation was primarily conceived of in economic terms by many officials in the EC. The EC's understanding of innovation as the development of new commercial products enabled the large private enterprises to play a leading role in the expertise discourse on H & FC as mainly these would have the financial means to make the huge investments required to commercialize different H & FC technologies such as for instance H & FC vehicles. In contrast, public research institutes and universities as well as smaller private companies did not possess these financial means. Hence the different actors of the EC such as the then Commissioner for Research, Philippe Busquin, and the representatives of large private enterprises shared the view that the promotion of H & FC should focus on the development of new commercial products which enabled them to assert this view in the expertise discourse on H & FC.

After they had asserted their views on H & FC, these policy entrepreneurs transferred the story line of the hydrogen economy from the expertise discourse into the policy discourse where they mobilized political support for it. The then Commissioner for Research, Philippe Busquin, played a key role in advocating the hydrogen economy to other Commissioners and officials of the EC as he naturally was in close contact with these. However, also the representatives of large private companies such as car manufacturers, oil companies, and energy utilities have a good access to the decision-makers in the EC granted by the importance of their companies for the European economy. In contrast, the scientists of public research institutes or the representatives of smaller companies were not granted a direct access to the decision-makers in the EC. Thus their resources in the form of time, access to the decision-makers in the EC, and financial means enabled the policy entrepreneurs to link the two discourses policy and expertise to each other and to play leading roles in the co-production of EU H & FC policy and expertise.

Finally, the launch of a European H & FC policy was further facilitated through the perceived lack of other promising technologies in the area of energy and transport and through the marginal critique of it raised only by few actors. The critics of H & FC were not only equipped with fewer resources than the main proponents but also the factual critique raised was not shared by the decision-makers in the EC. While individual Members of the European Green Party and representatives of environmental NGOs criticized that hydrogen production from nuclear energy sources would not be ecological and sustainable, the decision-makers in the EC did not perceive nuclear energy as problematic and regarded hydrogen production from nuclear energy as one among other viable options.

Thus the result of this first stage of the co-production of EU H & FC policy and expertise was the launch of the Hydrogen and Fuel Cell Technology Platform by the EC in 2004 and the stabilization of the vision of the hydrogen economy. The following chapter will explain the second stage in the co-production of EU H & FC policy and expertise including the implementation of the Hydrogen and Fuel Cell Technology Platform and the development of new expertise required for the launch of a Joint Technology Initiative for H & FC.

# 7 2004 – 2008: Launching a Joint Technology Initiative for H & FC

This chapter explains the co-production of EU H & FC policy and expertise in the years of 2004-2008 which resulted in the launch of a Joint Technology Initiative for H & FC in 2008. This period in time was categorized as the second stage in the co-production of EU H & FC policy and expertise for heuristic purposes. In this way it is highlighted that the co-production of EU H & FC policy and expertise at that period in time was most influenced by the stages of policy formulation and decision-making in the wider EU R&I policy. According to the policy cycle model, the stage of policy formulation is about the identification and definition of different policy options available, while the stage of decision-making is about the selection of one of those policy options through political decisions (Howlett, Ramesh, and Perl 2009; Jann and Wegrich 2003). It was these dynamics that dominated the wider EU R&I policy in the years of 2004-2008 and thus also influenced the co-production of EU H & FC policy and expertise at that time. This interpretation is supported by the empirical data collected for this thesis as will be shown throughout this chapter.

In fact, in the years of 2004-2008 the seventh FP was in preparation so that the EC had to take decisions on what technologies were to be promoted by what policy instruments. Among others, the EC had to decide what Technology Platforms of FP 6 were to become Joint Technology Initiatives in FP 7. This required formulating concrete development programmes to be pursued in FP 7 and situating the technologies to be promoted in the broader policy objectives of FP 7 and of the EC in general. As part of these general preparations of FP 7 the Hydrogen and Fuel Cell Technology Platform developed and published the Strategic Research Agenda and the Deployment Strategy in 2005 and on the basis of both developed an Implementation Plan which it published in 2007. All three documents outline a concrete development programme for H & FC that should be implemented through a Joint Technology Initiative. For this purpose, H & FC were situated as one among other new, low carbon energy technologies in FP 7. Indeed, the EC conducted, as required by EU legislation, an Impact Assessment in 2007 for the launch of a Joint

Technology Initiative for H & FC. In parallel the EC developed a proposal for the launch of a Joint Technology Initiative for H & FC which the Council of the EU adopted in 2008.

These illustrations already indicate the differences of this second stage in the co-production of EU H & FC policy and expertise in the years of 2004-2008 to the first stage that characterized the years of 2000-2004. In the first stage expertise was produced in order to raise political attention to H & FC and to set these technologies on the European innovation agenda. For this purpose, a very general vision of a future hydrogen economy was produced highlighting the future potential of H & FC to contribute to the achievement of the broader EU policy objectives such as economic growth and fighting climate change. In contrast, the second stage in the co-production of EU H & FC policy and expertise required the definition of a concrete development programme for H & FC that was to be implemented through a Joint Technology Initiative in FP 7. Thus, instead of highlighting the future potential of H & FC in general, concrete technical objectives had to be defined in order to illustrate what should be achieved by a Joint Technology Initiative for H & FC. Furthermore, in order to legitimize the launch of a Joint Technology Initiative, a specific role for H & FC had to be defined in relation to the other technologies that would be promoted in FP 7. Hence the expertise produced on H & FC differed considerably in the first and in the second stage of the co-production of EU H & FC policy and expertise due to the different roles that expertise played in these different stages of the policy process.

To explain the second stage in the co-production of EU H & FC policy and expertise which resulted in the launch of the Joint Technology Initiative on H & FC in more detail this chapter is split up into four parts. First, it is explained how this second stage in the co-production of EU H & FC policy and expertise was embedded in the preparations of FP 7 and thus influenced by the stages of policy formulation and decision-making in the wider EU R&I policy. Second, it is illustrated how the expertise required for legitimizing the launch of a Joint Technology Initiative was developed in the Hydrogen and Fuel Cell Technology Platform and in other H & FC projects funded by the EC under FP 6. Third, it is outlined how the expertise produced was fed into the policy discourse where it was used to justify the launch of a Joint

Technology Initiative for H & FC and to defend H & FC against its critics. Finally, the main insights of this chapter are summed up.

## 7.1 The second stage in the co-production of EU H & FC policy and expertise: H & FC in the preparations of FP 7

The co-production of EU H & FC policy and expertise in the time period of 2004-2008 was embedded in the stages of policy formulation and decision-making of the wider EU R&I policy. After the start of its new research and innovation agenda by the decision to launch twenty Technology Platforms in the first years of the new millennium (European Commission 2005c, 8), the EC had to formulate concrete development programmes and to decide upon which of the Technology Platforms should be converted into Joint Technology Initiatives in FP 7. Consequently, the production of expertise on H & FC was shaped by two major political requirements: 1) The need of a concrete H & FC development programme for FP 7 and 2) the need of expertise for deciding how to implement this development programme.

The formulation of the concrete development programmes that were to be implemented in FP 7 was conducted in the Technology Platforms of FP 6. In fact, the main objective of Technology Platforms in general is to develop "Strategic Research Agendas" which are to outline research priorities for the medium to long-term (European Commission 2004b, 13, 16). In addition to a Strategic Research Agenda, Technology Platforms should also develop a Deployment Strategy that illustrates how a specific technology is to be commercialized (European Commission 2004b, 13). Consequently, the Hydrogen and Fuel Cell Technology Platform developed a Strategic Research Agenda and a Deployment Strategy outlining a concrete development programme for H & FC that should be implemented in FP 7.

The implementation of the Strategic Research Agendas developed by the Technology Platforms in FP 6 was to be pursued in two ways in FP 7. In most cases the Strategic Research Agenda was to be implemented through the standard EU R&I policy approach of collaborative research which means that the EU was to implement the research agenda together with the Member States through open calls for proposals for collaborative research such as, for example, integrated projects (European Commission 2004b, 19). However, in a certain number of cases the EC expected the research agenda to be of a scale that required "the mobilisation of very high public and private investments, as well as a large critical mass of researchers throughout Europe and even beyond" (European Commission 2004b, 19). For these cases the EC intended to apply its new policy instrument of Joint Technology Initiatives.

JTIs are a policy instrument in EU R&I policy which the EC introduced in its seventh FP with the objective to centralize all funding in specific technological areas in one single European instrument. JTIs were to emerge from Technology Platforms and to provide a suitable tool for the implementation of the research and development agendas that required a scale and scope that exceeded the usual EU R&I approach of collaborative research. Hence JTIs were one of the new policy instruments for the promotion of innovation that the EC wanted to apply for specific technological areas in FP 7. JTIs were to constitute full public-private partnerships designed to implement large-scale, applied and industrial research programmes. For this purpose, they would be equipped with their own budget, which is why their proposal would have to be approved by the European Council and the EP (European Commission 2004b, 20).

The launch of JTIs requires the conduction of a formal Impact Assessment of the EC in which it has to be demonstrated that a JTI is a better policy option for the case in question than the policy approach of collaborative research. For this purpose, the fulfilment of five specific criteria has to be demonstrated. First, the JTI has to constitute a "unique contribution to Europe's industrial competitiveness in strategic technologies" (European Commission 2005a, 10). Second, the existence of a market failure preventing the usual development of the technology in question has to be demonstrated. Third, it has to be demonstrated that the implementation of a JTI will lead to an additional European value that goes beyond that what the Member States could have achieved on their own. Fourth, a substantial, long-term commitment from the industrial actors involved has to be demonstrated. Fifth, it has to be demonstrated that the already existing policy instruments for the promotion of the technology cannot achieve the desired outcomes (European Commission 2005a, 11–13).

In sum, the formulation of a concrete development programme and the legitimization of its implementation through a JTI in FP 7 constituted the two main aspects shaping the co-production of EU H & FC policy and expertise in the years of 2004-2008. The following two subchapters will illustrate this process in more detail. First, subchapter 7.2 will explain the formulation of a European H & FC development programme and the production of the expertise required for legitimizing its implementation through a JTI in FP 7 in the expertise discourse on H & FC. Thereafter, subchapter 7.3 illustrates how this expertise was fed into the policy discourse in order to promote the launch of a JTI for H & FC and to defend it against its critics.

## 7.2 The expertise discourse: Formulating a European H & FC development programme and producing the expertise for its legitimization

The production of expertise in the time from 2004-2008 was characterized by the preparation of the seventh FP of the EC. The actors driving the expertise discourse on H & FC shared the political objective of launching a Joint Technology Initiative (hereinafter JTI) for H & FC under FP 7. This purpose required a different type of expertise than the one needed for setting H & FC on the European agenda as it had to be illustrated what concrete objectives are to be achieved with a JTI for H & FC and how these would fit into the overall objectives of FP 7. While setting H & FC on the agenda required highlighting the future potential of these technologies in rather general terms in order to raise the attention directed to the technologies, the launch of a JTI demanded the definition of a concrete H & FC development programme and its objectives as well as the fulfilment of the EC's specific criteria for the launch of a JTI.

The expertise required was produced in the Hydrogen and Fuel Cell Technology Platform and in further H & FC projects funded by the EC under FP 6. To illustrate this development of expertise, the subchapter at hand is split into three parts. First, the operation of the Hydrogen and Fuel Cell Technology Platform (hereinafter HFP) in general is described, as this is necessary for the reader to understand how the production of expertise took place. Second, it is explained how a European H & FC development programme was defined in the three key documents of the HFP: The Strategic Research Agenda, the Deployment Strategy, and the Implementation Plan. Third, it is outlined how the expertise required for situating H & FC in FP 7 and for legitimizing the launch of a JTI was developed. In addition, throughout the three different parts of this subchapter it is emphasized that actors equipped with the necessary resources such as high-ranking officials of the EC and the representatives of large private enterprises dominated the production of expertise and ensured that their view on H & FC is asserted.

### 7.2.1 The Hydrogen and Fuel Cell Technology Platform

This subchapter is to explain how the formal governance structure of the HFP came into being and how it was supposed to work. It is important to present this formal governance structure to the reader because it had an impact on the production of expertise and because the formal governance structure of the Joint Technology Initiative for H & FC was built on it. Thus the following paragraphs are first to explain the general features of the EC's new policy instrument of Technology Platforms. Thereafter, the formal governance structure of the Hydrogen and Fuel Cell Technology Platform is described.

*General features of Technology Platforms*

Technology Platforms (hereinafter TP) are supposed to bring together a wide range of different actors in certain technological areas with the industry playing a leading role and the EC overseeing and supporting their development (European Commission 2004b, 12). The key objectives of TPs are to develop Strategic Research Agendas and Deployment Strategies, to mobilize private and public investments required for their implementation, to identify the education and training activities that will be needed to develop a high-skilled work force able to deal with the technology in the future, and to raise public awareness and legitimation of the technology in question (European Commission 2004b, 13). Hence the production of expertise in the form of concrete development programmes for specific technologies constitutes one of the key objectives of TPs.

While TPs are to be driven by the "key industrial concerns", they are not only to encompass large, medium, and small enterprises but also public authorities at European, national, regional, and local level, public research institutes, the financial community and the civil society as well as users and consumers (European Commission 2004b, 14). A particular focus is put on the active involvement of the Member States so that these can coordinate national research activities with the objectives of the TP (European Commission 2004b, 16). All of these actors are "to pull together around a commonly formulated approach for the technological field concerned, covering the complete chain from research and technological development through to future market penetration" (European Commission 2004b, 15).

Hence the general approach of TP's reflects very well the EC's new understanding of innovation with a clear focus on economic impacts and the industry leading the process. TPs were to contribute to increasing the EU's competitiveness through the development of new technologies that would lead to radical change in a sector, the reconciliation of different policy objectives with regard to sustainable development, the development of new technology based public goods or services with high entry barriers but high economic and social potential, the development of technology breakthroughs necessary to bring the EU into a leading position in high-technology sectors, and the renewal, revival or restructuring of traditional industrial sectors. The TP on H & FC was seen as an example that should lead to the development of new technologies that would radically change a sector (European Commission 2004b, 17).

The EC could launch the Hydrogen and Fuel Cell Technology Platform without the approval of the European Parliament and the Council of the European Union as there have not been any formal processes and criteria for the launch of Technology Platforms at the beginning.[9] This is, among others, due to the fact that Technology Platforms are not set up as legal entities equipped with their own budget for project funding but rather can be conceived of as networking platforms whose organization can be supported by the EC with human and financial resources. Hence the main objective is to gather a wide range of different actors who are interested in a specific technological area in a common platform.

*The formal governance structure of the Hydrogen and Fuel Cell Technology Platform*

Apart from the ambition to include a wide range of different actors with a leading role reserved for the industry, the EC did not have any formal, unitary template of how the organization of TPs should look like. Therefore, the organizational structure of each TP was adapted to the specific conditions prevailing in the technological area in question. Furthermore, the organizational structure was inspired by the development of similar policy instruments in other countries such as the USA and Germany. The organizational structure of the Hydrogen and Fuel Cell Technology Platform (hereinafter HFP) is depicted in the figure below:

9 First in the preparation of Horizon 2020 the EC has defined a set of criteria to keep the launch of new Technology Platforms within a limit (European Commission 2013b, 4). Thus new Technology Platforms have to be in line with the Europe 2020 priorities and objectives, they have to represent a sizeable proportion of a current or future potential market, they have to be of an added value for Europe, they have to be transparent in its activities and open to new members, they should foster interdisciplinary and cross-sector work, and the industry and member states included should show a high level of commitment to achieve the objectives of the Technology Platform (European Commission 2013b, 5).

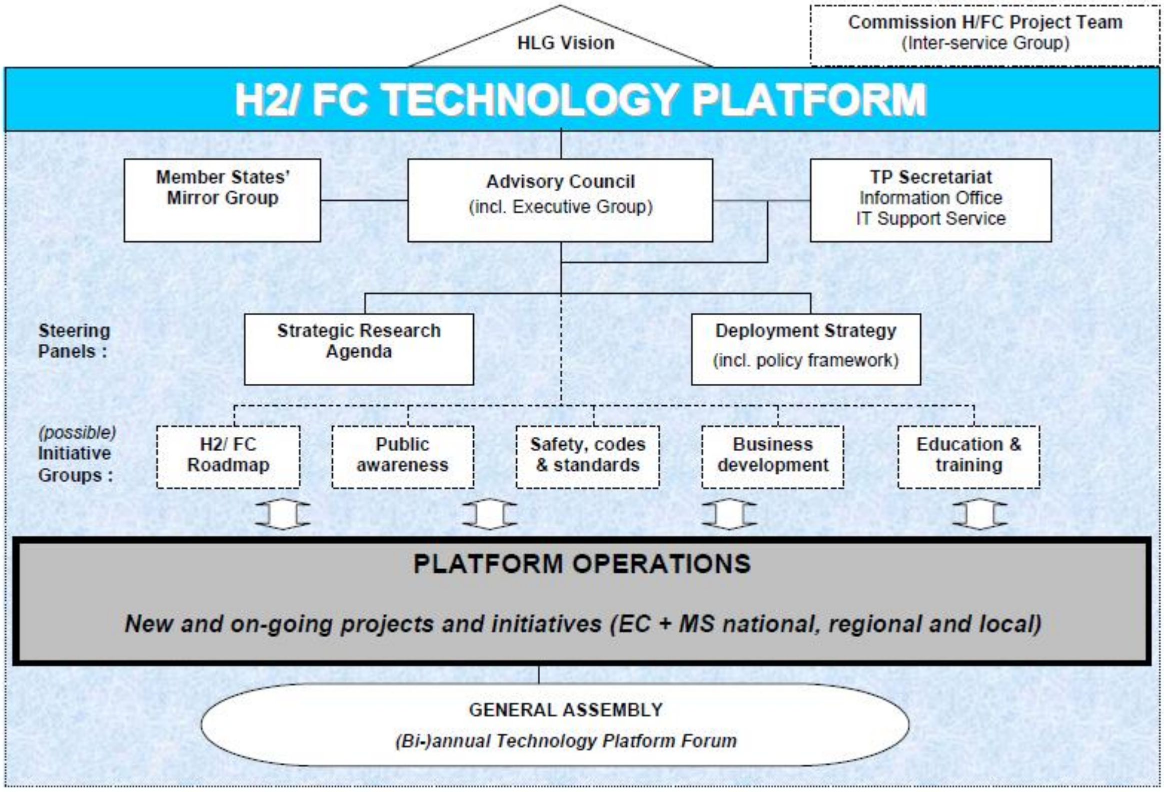



**Figure 11**, The European Hydrogen & Fuel Cell Technology Platform

Source: (European Hydrogen & Fuel Cell Technology Platform 2003b, 15)

The main governing body of the HFP was the Advisory Council that should guide the overall development of the TP according to the vision of the hydrogen economy which was developed by the High Level Group as explained in subchapter 5.2. For this purpose, the Advisory Council should organize a plenary session at least twice a year in order to ensure an efficient operation of the HFP and to discuss the general direction of its further development (European Hydrogen & Fuel Cell Technology Platform 2003a).

The Advisory Council was composed of 36 persons of which the large majority represented industrial companies such as car manufacturers and oil companies (European Hydrogen & Fuel Cell Technology Platform 2004a, 1, 2). However, the Advisory Council of the HFP also included two representatives of the NGOs Greenpeace and the World-Wide Fund for Nature (hereinafter WWF) and three officials of the EC from DG RTD, DG TREN, and DG JRC as well as several representatives from public research institutes and national research agencies (European Hydrogen & Fuel Cell Technology Platform 2004a, 1, 2). Hence the composition of the Advisory Council reflected the EC's general understanding of innovation which emphasized the inclusion of a wide range of different actors so that small and medium sized enterprises, public research institutes, and civil society organizations should be represented in the Advisory Council.

In order to assist the work of the Advisory Council an Executive Group was set up consisting of six persons. The Executive Group should implement the strategic decisions taken by the Advisory Council and it should coordinate the work between the two Steering Panels and the Initiative Groups set up. Furthermore, it should develop proposals on the further development of the HFP and suggest issues that the members of the Advisory Council should discuss and decide upon. In so doing, the Executive Group was to maintain a close cooperation with the Secretariat of the HFP.

The Mirror Group reflected the EC's general ambition behind the idea of TPs to establish European research areas with the involvement of the Member States. It was composed of representatives of the Member States who came from national research ministries or agencies. The policy officers of the EC managing and overseeing the development of the HFP contacted the national organizations and asked them to select a person that would represent them in the Mirror Group. These representatives should coordinate the European research objectives agreed upon in the HFP with the national research projects on H & FC in order to achieve synergies and to avoid duplication.

In addition to the Advisory Council and the Mirror Group, the EC had its project team that was composed of policy officers from different DGs. Also the Secretariat of the TP was composed of policy and scientific officers of the EC and its JRC who assisted the Advisory Council in administrative and organizational issues. Furthermore, there were two Steering Panels that oversaw the development of the two main documents that the TP should deliver: The Strategic Research Agenda and the Deployment Strategy. Both included a wide range of actors representing the different sectors with an interest in H & FC.

The actors involved in the set-up of the HFP agreed upon the need to establish Initiative Groups on the different issues that were regarded as important alongside the commercialization of H & FC such as “safety, codes & standards” or “education & training” as depicted by the figure above. Any actors that were interested in the development of the issue in question could join the specific Initiative Group. Each of the Initiative Groups should have a chairman that reports the issues discussed and the progress achieved to the Advisory Council. Also new Initiative Groups could be proposed to the Advisory Council which would decide upon their establishment.

The last bit in the official governance structure of the TP is the General Assembly which was assessed by many actors as a useful tool in the development of H & FC in Germany and the USA and was thus introduced in the HFP as well. The General Assembly is an annual meeting over two days open to all actors with an interest in H & FC. It provides a forum where the progress achieved in the overall development of H & FC and the general direction of the further development required are discussed. At the time of the HFP around 200 persons attended the General Assembly each year.

### 7.2.2 Formulating a European H & FC development programme

This subchapter explains how a European H & FC development programme was formulated in the HFP in order to justify the launch of a JTI for H & FC. In fact, the main objective of the HFP was to develop a Strategic Research Agenda and a Deployment Strategy for H & FC which were needed to demonstrate that there is a concrete development plan for H & FC for FP 7. The final versions of both documents were published in 2005. Later on, the Strategic Research Agenda and the Deployment Plan were merged into the Implementation Plan to have one single document that laid out the research and development agenda that should be implemented by the JTI on H & FC under FP 7. The Implementation Plan was published in 2007 stating that the actors involved in its development agreed upon needing € 7.6 billion for the realization of the objectives outlined and thus the successful commercialization of H & FC.

The European H & FC development programme outlined in the Implementation Plan of the HFP comprised two main elements. First, it illustrated the different technological areas of H & FC that should be promoted in FP 7. Second, it outlined the concrete technical objectives that should be pursued in these technological areas. Therefore, the following paragraphs are to explain how these different technological areas of H & FC were defined and how concrete technical objectives were developed by the actors involved in the HFP. In doing this, it is also highlighted that not all actors had the same influence on the definition of the different technological areas and the technical objectives but rather high-ranking officials of the EC and large enterprises such as car manufacturers and energy utilities from Germany took a leading position and influenced the formulation of the European H & FC development programme more than other actors.

*Defining the different technological areas of H & FC to be promoted in FP 7*

The actors of the HFP defined the different technological areas in the field of H & FC that should guide the development of these technologies in FP 7. This was first done in the Strategic Research Agenda and in the Deployment Strategy and thereafter further refined and specified in the Implementation Plan so that the initially defined technological areas slightly changed over the time. Eventually, four main areas of applications were defined: 1) Hydrogen production, 2) Transport applications, 3) Stationary applications, and 4) Early market applications. These areas differed with regard to the specific technologies that should be developed and with regard to the actors that would be developing them.

Hydrogen production was considered as a technological area on its own. In the case of fuel cells it was agreed to have separate working groups for stationary and for transport applications because it was assumed that different technologies would be needed for both areas of application due to different technical requirements, different groups of consumers, and different manufacturers. Therefore, two separate technological areas for stationary and transport applications were defined for fuel cells. In addition, one technological area was defined as “early market applications” because it was assumed that specific niche applications such as fuel cell forklifts and fuel cells for recreational vehicles would be commercialized earlier than other applications due to the specific technical requirements and conditions prevailing in these areas.

The different working groups built for each area of application worked on the basis of draft papers which were developed and then circulated among the members so that all of them could comment and raise questions. During this iterative process the actors involved attempted to make sure that their interests and views are well represented in the final agreement. For instance, in the working group on hydrogen production different actors made sure that hydrogen production from renewable, fossil and nuclear energies was included according to their view on these different energy sources. The issue of hydrogen production from nuclear energy evoked opposition from an environmental NGO involved in the working group. However, as most actors were either in favour or at least not opposed to hydrogen production from nuclear energy, this issue was included as one option among others in the final agreement.

As already indicated above, not all actors asserted the same influence on the definition of the specific hurdles and objectives in the different areas of application. The large car manufacturers from Germany for instance dominated the working group on transport applications. This was partly because they already had a clear view on the development of H & FC and a lot of expertise accumulated in their involvement in the German H & FC projects. Another reason, however, was that the car manufacturers from other countries did not invest as many resources in the development of H & FC as the German ones did. The representatives of companies such as Renault and Toyota for example attended the meetings of the working group rather to observe the development than to actively shape it. In contrast, companies such as BMW and even more so Daimler had a clear view on H & FC so that their representatives proactively promoted this view and eventually had most impact upon defining the hurdles and the objectives in the development of automotive H & FC applications.

Also the working group on hydrogen production included large enterprises such as oil companies, energy utilities, and gas supplying companies. Many of these took a very careful approach to sharing their data and information on hydrogen production with the other participants. For many companies it was a very sensitive issue to share the information on what specific technologies they are working on and what their specific interests are with their actual competitors. In this case it was partly the role of higher-ranking officials of the EC and of the representatives of companies not involved in hydrogen production to facilitate compromises and to trigger the production of expertise. These higher-ranking officials of the EC as well as the representatives of companies not involved in hydrogen production invested large resources in form of time in order to facilitate the definition of a technological agenda and technical objectives in the area of hydrogen production as a complete development programme for all H & FC applications areas was needed for the political discussions on the launch of a JTI on H & FC.

In contrast to the working groups on transport applications and hydrogen production, the area of stationary applications did not include any larger companies but rather was characterized by small- and medium-sized companies working on the development of different types of fuel cells and by public research institutes. Hence stationary H & FC applications were being developed by a different group of actors equipped with fewer resources than their counterparts in the application areas of transport and hydrogen production. Also the area of early market applications was driven by small- and medium-sized companies and public research institutes. While these different constellations of actors across the different working groups did not play a huge role in the definition of the technical priorities and objectives in the HFP, they were to become important in the next stage of EU H & FC policy when the overall funding available had to be distributed among the different areas of application in the implementation of the JTI on H & FC.

*Defining the technical objectives to be achieved by a JTI on H & FC*

The development of expertise in the HFP was guided by the political objective of launching a JTI on H & FC in FP 7. For this purpose, concrete technical objectives that were to be achieved by this JTI had to be put forward. The technical objectives outlined in the so-called Snapshot 2020 provide a prime example of this. The year 2020 is the main reference for many concrete energy and transport policy objectives of the EC which are to be achieved by then. Hence also the actors of the HFP defined concrete technical targets for the area of H & FC that should be achieved by 2020:

| | **Portable FCs** for handheld electronic devices | **Portable Generators & Early Markets** | **Stationary FCs** Combined Heat and Power (CHP) | **Road Transport** |
|---|---|---|---|---|
| ***EU*** $H_2$/ FC units sold per year projection 2020 | ~ 250 million | ~ 100,000 per year (~ 1 $GW_e$) | 100,000 to 200,000 per year (2-4 $GW_e$) | 0.4 million to 1.8 million |
| ***EU*** cumulative sales projections until 2020 | n.a. | ~ 600,000 (~ 6 $GW_e$) | 400,000 to 800,000 (8-16 $GW_e$) | 1-5 million |
| ***EU*** Expected 2020 Market Status | **Established** | **Established** | **Growth** | **Mass market roll-out** |
| Average power FC system | 15 W | 10 kW | <100 kW (Micro HP) >100 kW (industrial CHP) | 80 kW |
| FC system cost target | 1-2 €/ W | 500 €/kW | 2000 €/kW (Micro) 1.000-1.500 €/kW (industrial CHP) | < 100 €/kW (for 150.000 units per year) |

**Table 8**, Snapshot 2020

Source: (European Hydrogen & Fuel Cell Technology Platform 2007, 15)

The concrete targets and numbers of Snapshot 2020 were first developed in the different technological working groups. Finally, the snapshot 2020 targets were discussed between all actors involved in the HFP. All of these actors have their own, internal analyses and expectations on the further development of H & FC inside of their organizations. While these internal analyses are usually not revealed to others, all actors made statements based on these analyses in the common discussions. In the end, the actors involved agreed upon concrete numbers and targets somewhere in the middle of all the suggestions made. However, most of the actors involved did not regard these concrete objectives as anything more than mere estimations and perceived them rather as rough points of orientation than as actual targets and binding commitments.

Still, Snapshot 2020 constitutes a prime example of the co-production of policy and expertise and the leading role of specific policy entrepreneurs in this process. While many of the actors involved in the expertise discourse on H & FC are rather sceptical on concrete forecasts over more than fifteen or twenty years into the future, these forecasts were needed for the political discussions on the launch of the JTI: “I do not take these numbers too serious but, of course, they can have a political weight” (Interviewee 1, 2011). In order to justify the launch of a JTI for H & FC it had to be shown what concrete objectives are to be achieved by it. For this purpose, quantified objectives are a useful tool to illustrate the future potential of H & FC to actors who are not involved in the expertise discourse on H & FC and who do not know much about these technologies in general. Having 0.4 to 1.8 million H & FC vehicles sold by 2020 constitutes for instance a very clear objective that even people without any knowledge on H & FC can relate to and that can be used to situate H & FC in relation to other technologies in the overall objectives of FP 7.

Indeed, the empirical data analyzed for this thesis confirm that the development of Snapshot 2020 was initiated by specific policy entrepreneurs that acted at the interface of policy and expertise and that needed these concrete objectives to be developed in the expertise discourse on H & FC in order to use them in the policy discourse on H & FC. These policy entrepreneurs were, above all, high-ranking officials in the EC at the Director and Director-General level as well as the representatives of large enterprises such as car manufacturers and oil companies who predominantly came from Germany and invested more resources in the promotion of H & FC than other actors involved in the HFP. However, this leading position of some actors did not cause any larger opposition in the expertise discourse on H & FC at this stage of EU H & FC policy as all of the actors involved supported the launch of a JTI for H & FC and argued for it.

Hence this expertise on H & FC was developed in order to fulfil a specific role in the policy process and this specific role provided the form for the content of the expertise produced. It is important to emphasize this distinction between the form and the content, as the specific role of the expertise in the policy process did not determine the concrete numbers of the H & FC vehicles that were to be sold by 2020 but only that these concrete numbers had to be developed. In other words, while the requirement to estimate the number of H & FC vehicles came from the policy discourse, the estimation of the concrete numbers took place in the expertise discourse on H & FC. In this way specific policy entrepreneurs in the EC and in private companies who were equipped with the necessary resources to play a key role in both discourses connected the two discourses to each other.

Hence an important role of these policy entrepreneurs was to ensure that the actors of the HFP develop that type of expertise that will be needed to justify the launch of a JTI on H & FC in FP 7. For this purpose, they facilitated agreements between different actors and provided the overall frame for the development of expertise. Furthermore, both the high-ranking officials of the EC as well as the representatives of the large private companies ensured the consistency of the expertise produced across the reports of the HFP. Thus they ensured that there are no contradictory statements in the different reports and aligned all actors involved on some central statements. This consistency across the reports increased the validity and the political weight of the expertise developed. However, this does not mean that all of these reports had to include exactly the same numbers but rather that differing numbers had to be explained through for instance different assumptions on the future development of key parameters and that it has to be explained why these assumptions differ from those in other reports.

In fact, the ensured consistency across the reports of the HFP and other studies on H & FC funded by the EC by the policy entrepreneurs points to the relation between the story lines of the policy discourse and the development of expertise in the expertise discourse. The actual influence of a story line in the policy discourse depends on how many and on what actors support it. Therefore, the high-ranking officials of the EC who promoted the launch of a JTI on H & FC aligned as many actors as possible around the same story line in order to portray a coherent discourse coalition supportive of H & FC in the policy discourse. The following quotation of a representative of a private company who participated in the discussions on the launch of the JTI supports this interpretation:

> "The Commission tends to settle everything beforehand so that there is not any apparent dissent when an issue is going to be discussed in the Parliament. … There is some draft paper that includes certain formulations and then it is agreed upon these formulations and the Commission puts high emphasis on that one should only use these formulations and no other ones." (Interviewee 3, 2011)

The quotation illustrates once more how the production of expertise in the expertise discourse was influence by the political objectives that were pursued in the policy discourse. Expertise was produced in order to fulfil a specific role in the policy discourse. More specifically, the expertise produced by the HFP was to be used to justify the launch of a JTI on H & FC in FP 7. Therefore, those actors who intended to use the expertise in that way made sure that the expertise produced suits this usage. Hence the expertise on H & FC had to include quantified objectives for the development of H & FC as these could be used to situate H & FC in the overall technology portfolio of FP 7 and to illustrate the potential of H & FC to policy-makers who have only little knowledge about these technologies. Furthermore, the consistency of the expertise produced was ensured across several reports of the HFP in order to increase its validity and political weight. It was also made sure that different actors align around the expertise produced in order to portray that there is a coherent discourse coalition supporting the launch of a JTI on H & FC.

### 7.2.3 Situating H & FC in FP 7 and legitimizing the launch of a JTI

This subchapter explains how expertise was produced in order to situate H & FC in FP 7 and to legitimize the launch of a JTI for H & FC. This expertise was partly developed in the HFP and partly in further projects such as CONCAWE/EUCAR/JRC, HyWays, and WETO-H2 which have been carried out by a wide range of different actors. These projects have resulted in studies and reports that outline the future potential of H & FC with regard to their expected ecologic and economic impact in terms of costs and reduction of GHG emissions. The expertise produced in these projects has been used in the Implementation Plan of the HFP and in the Impact Assessment (hereinafter IA) conducted later on in order to justify the launch of a JTI on H & FC in FP 7. Hence the production of expertise was guided by the political objective to launch a JTI on H & FC and the thereof resulting requirements to situate H & FC among the related technologies to be promoted in FP 7 and to legitimize the launch of a JTI for H & FC.

These relations between the political negotiations and the production of expertise have been brought about by specific policy entrepreneurs who linked the two discourses on policy and expertise to each other in order to justify the launch of a JTI for H & FC. High-ranking officials of the EC and the representatives of large enterprises such as car manufacturers and oil companies have guided the production of expertise on H & FC so that they can use it in the political negotiations on the launch of a JTI. For this purpose, concrete data on the technical performance of H & FC expected in the future was produced in order to situate H & FC as new, low carbon energy technologies in FP 7. Furthermore, expertise was developed in order to illustrate that the specific criteria for the launch of a JTI are fulfilled in the case of H & FC.

Therefore, the following paragraphs will first illustrate how the expertise required to situate H & FC as new, low carbon energy technologies in FP 7 was produced. Thereafter, it will be explained how the expertise required to demonstrate that the specific criteria for the launch of a JTI are met was produced.

*Fuel cells and hydrogen as new, low carbon energy technologies*

In order to situate H & FC in FP 7, these technologies were not portrayed as the key components of a revolutionary hydrogen economy anymore but rather as one among several other new energy technologies that could contribute to an emission-free energy system in the future. Furthermore, the focus was shifted from hydrogen to fuel cells as a certain number of people in the EC were sceptical on the future potential of hydrogen, while fuel cells were less controversial and assessed more positive. Therefore, the supporters of H & FC inside and outside of the EC decided to not speak of hydrogen and fuel cells anymore but rather of fuel cells and hydrogen in order to cause less opposition to these technologies in the EC.

The expertise required for portraying fuel cells and hydrogen as new, low carbon energy technologies was developed in several reports and studies such as the Implementation Plan of the HFP, the HyWays report, the HyLights report, the Roads2Hycom report, the WETO-H2 study, and the EUCAR/CONCAWE/JRC study. Although a wide range of different actors was involved in the development of these studies and reports, the production of expertise was mainly influenced by specific policy entrepreneurs who were equipped with the necessary resources to ensure that the expertise required for portraying H & FC as new, low carbon energy technologies was produced as will be outlined in the following paragraphs.

The main objective of the HyWays project, which was coordinated by the German consultancy LBST, was that the representatives of the Member States involved in the project should develop concrete strategies of how H & FC could fit in their national energy system and how these different strategies could be coordinated with each other. For this purpose, concrete data on the expected performance of H & FC in the future were developed. However, while the project coordinator and the representatives of the Member States were the ones who actually carried out the project, they were not the ones who had the largest impact on the development of expertise. Rather, it was high-ranking officials of the EC and the representatives of large private companies such as car manufacturers and energy utilities who ensured that the expertise developed on H & FC was in line with their view on these technologies.

This large impact of the specific policy entrepreneurs relied on the resources in form or time, information, and financial means available to them. Above all large car manufacturers such as Daimler and BMW or oil companies such as Shell and Total had good access to the officials of the EC and to the other organizations involved in the development of the different expert reports on the future potential of H & FC. These companies provided the technical data such as for instance the efficiency of state of the art fuel cell systems or electrolysers for hydrogen production for all of the expert reports developed. Consequently, these large enterprises had together with the high-ranking officials of the EC the largest impact on the development of expertise as the following quotation of a representative of a private company in the different projects under FP 6 illustrates:

> "The final report of HyWays confirms the numbers of the Strategic Research Agenda, the Deployment Strategy and the Implementation Plan because the documents which were developed there and the insights in HyWays that came from the industry were perfectly adjusted to each other. The Commission ensured that there are no inconsistencies between the HyWays report and the documents of the Hydrogen and Fuel Cell Technology Platform. ... And one should not forget that the most important link between HyWays and the Commission was the industry. The industry was in contact with both the Commission and with us. This means that Daimler and BMW, which of course have been closely involved in the projects, they took care of ensuring the consistency of the data so that not completely different scenarios were being developed, or also Total and the energy utilities." (Interviewee 5, 2012)

The same policy entrepreneurs have also dominated the development of the so-called CONCAWE/EUCAR/JRC reports which constitute an important data base for the assessment of the future development of alternative fuels and powertrains. The cooperation between CONCAWE, which is the oil companies' European organization for environmental, health, and safety issues, EUCAR, which is the European Council for automotive R&D, and the Institute for Energy and Transport of the JRC began in the year 2000 with the objective of assessing the future potential of alternative transport fuels and powertrains (Joint Research Centre 2014d). The results of this cooperation are regularly published in the "Well-to-Wheel Analysis" reports which outline the overall energy efficiency of different fuels and powertrains from the production of the fuel to its use for vehicle propulsion. Hence the cooperation between CONCAWE, EUCAR and the JRC constitutes a continuous process resulting in regular updates of the expertise on the potential of hydrogen as a future transport fuel.

On the basis of the technical expertise of the HyWays report and the EUCAR/CONCAWE/JRC study H & FC were portrayed as having a huge potential in reducing emissions and energy consumption in the energy and transport system. The figure beneath, for example, which was later on used in the Impact Assessment to legitimize the launch of a JTI for H & FC, is taken from the HyWays report:

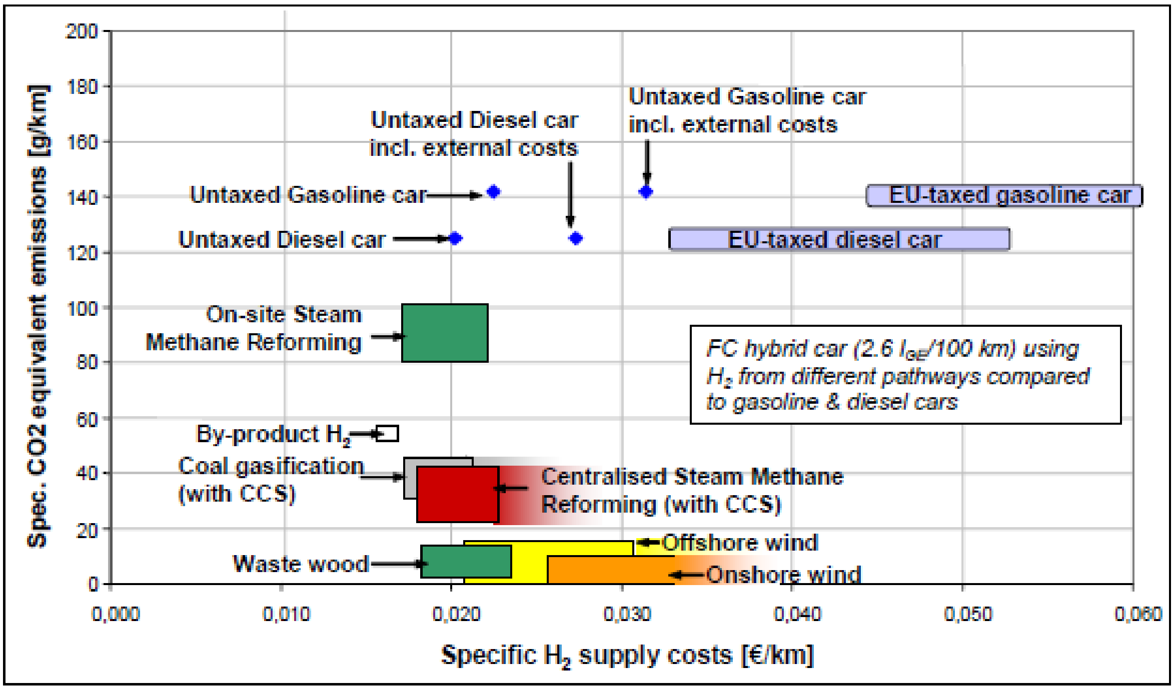



**Figure 12**, Projected $CO_2$ emissions and costs for H & FC, gasoline, and diesel vehicles by 2030

Source: (European Commission 2007b, 11)

The figure is to illustrate that fuel cell vehicles powered by hydrogen would contribute to significant $CO_2$ emission reductions under all different hydrogen production pathways and that they are likely to become economically competitive to vehicles powered by gasoline and diesel by 2030 under specific assumptions. The projections are based on an oil price of 50 €/barrel and technological progress and learning effects in the development of H & FC (European Commission 2007b, 11). Hence the expertise developed in the HyWays project was used to portray H & FC as new, low carbon energy technologies and to legitimize the launch of a JTI in the Impact Assessment.

The policy entrepreneurs from the EC and the large private companies also asserted their influence in the "Alternative Fuels Contact Group" of the EC which was set up in 2002 with the task to provide economic and technical advice on the future potential and development of alternative fuels for road transport (Alternative Fuels Contact Group 2003, 2).

The “Alternative Fuels Contact Group” should have a particular focus on natural gas and hydrogen and elaborate suitable measures by which the EU could promote the use of these fuels (Alternative Fuels Contact Group 2003, 2). The background behind the set up of this expert group is the emerging European Transport Policy and in particular the EC White Paper on a common transport policy from 2001 in which the EC suggests to raise the share of alternative transport fuels in the overall transport system to 20% by 2020 (Alternative Fuels Contact Group 2003, 4; European Commission 2001g, 79). The “Alternative Fuels Contact Group” published its first main expert report “Market Development of Alternative Fuels” in December 2003 outlining biofuels, natural gas, and hydrogen as the most promising options to achieve the EC’s transport policy objectives by 2020 (Alternative Fuels Contact Group 2003, 4).

In addition to these expert reports, the policy entrepreneurs also succeeded in establishing H & FC as new, low carbon energy technologies in several Communications and Green Papers of the EC. Indeed, the EC intensified its efforts to develop a European energy policy and even more so the ambition to develop a European policy for new energy technologies. The European Council requested the EC to develop a coherent energy strategy for Europe at an informal meeting in British Hampton Court in October 2005 (Geden and Fischer 2008, 45; Pollak, Schubert, and Slominski 2010, 90, 91). This triggered the publication of several energy related Green Papers and Communications by the EC in 2006 and 2007 (Geden and Fischer 2008, 30, 39-41; Pollak, Schubert, and Slominski 2010, 91, 92, 105, 107). The Green Paper “A European Strategy for sustainable, competitive and secure energy” from 2006, the Communication “An Energy Policy for Europe” from 2007, and the Communication “A European Strategic Energy Technology Plan” from 2007 were the three most important publications outlining the general features of the European energy policy envisioned.

The Green Paper of the EC “A European Strategy for sustainable, competitive and secure energy” from 2006 emphasizes that there is no single solution to Europe’s energy problems, but rather that there is a wide portfolio of technologies that will be needed among which H & FC (European Commission 2006g, 13). Also in the EC's Communication "An Energy Policy for Europe" from 2007 H & FC are described as part of the EC's long-term low carbon strategy for the transport sector after 2030 and as vital parts of the EU's sustainable energy system after 2050 (European Commission 2007e, 15, 16). In its Communication "A European Strategic Energy Technology Plan" the EC argues that new, low carbon energy technologies are needed to achieve the EU's energy policy objectives such as the reduction of GHG emissions and of the overall energy consumption (European Commission 2007d, 2). According to the EC urgent action is needed as investments in energy research have been declining in the last two decades, the EU is underperforming in innovations in energy technologies, and other countries such as the USA, Japan, China, Brazil, and India have already began intensifying their efforts (European Commission 2007d, 3, 4). Therefore, a new European policy for energy technologies is required (European Commission 2007d, 8).

Consequently, the Strategic Energy Technology Plan (hereinafter SET Plan) of the EC was to outline all the new energy technologies needed to achieve the EU energy policy objectives (European Commission 2007d, 2-4). In the SET Plan H & FC are described as part of the EC's vision for a completely decarbonized economy by 2050 even if they may only have little impact on the targets for 2020 (European Commission 2007d, 5, 6). Thus the policy entrepreneurs from the EC and the large private enterprises succeeded in portraying H & FC as one of these new, low carbon energy technologies.

*Meeting the specific criteria for the launch of a Joint Technology Initiative*

In order to launch a JTI for H & FC in FP 7 the supporters of H & FC not only had to establish the view of H & FC as new, low carbon energy technologies in the EC but also had to demonstrate in an Impact Assessment that a JTI is the most viable policy option for the promotion of these technologies. Consequently, expertise was developed to demonstrate that the five specific criteria for the launch of a JTI are met. These five specific criteria are: 1)

The JTI has to contribute to the EU's industrial competitiveness in strategic technologies, 2) A market failure has to prevent the development of the technology in question, 3) The JTI should have an additional European value that the Member States could not achieve on their own, 4) The industrial actors involved have to demonstrate their substantial, long-term commitment to the development of the technology in question, and 5) Already existing policy instruments cannot achieve the desired outcomes (European Commission 2005a, 10–13). The following paragraphs are to illustrate how the expertise required to demonstrate that these criteria are met was developed.

To illustrate the strategic importance of H & FC for the industrial competitiveness of the EU, the development of these technologies in Japan and in the USA was emphasized. The main point was that the USA and Japan are investing huge financial resources into the development of H & FC which was to result in a competitive advantage for the American and Japanese companies developing H & FC compared to the European companies. If the EU wanted to compete with the USA and Japan in the development of H & FC, it would have to increase its financial efforts considerably, otherwise there might not be any H & FC sector in the EU in the future because all of the private companies would shift their H & FC activities to the USA and Japan where they could receive public support for them. Thus it was argued that the EU has to launch a JTI for H & FC if it wants to develop a future H & FC sector in Europe.

Furthermore, it was emphasized that the utilization of the future potential of H & FC as new, low carbon energy technologies is to be hampered by a market failure which is one of the main reasons why a JTI is to be needed. The existence of this market failure was for instance outlined in an industry submission to the Impact Assessment of the EC which was prepared by the industrial companies that participated in the HFP (European Commission 2007b, 20). In this submission the industrial companies argued that the market failure was to consist of the long time of development and the high degree of coordination required in the area of H & FC before these technologies can finally be commercialized because due to these issues the return of investment for the companies involved would be at risk. This uncertainty was to make the required investments in H & FC rather risky which eventually would prevent the companies involved from making them. Therefore, it was argued that public support in the form of a JTI is needed to foster coordination and to stimulate investment in the area of H & FC (European Commission 2007b, 12-14) in order to overcome the existing market failure hampering the development of these technologies.

The additional European value of a JTI for H & FC and the advantages of a JTI over existing policy instruments by various arguments and expertise. It was for instance argued that the launch of the JTI would lower the administrative costs as these would be shared equally between the EC and the industrial stakeholders, allow the industry to take a leading role in the development, and allow for a fixed budget and a long-term strategy for the development of H & FC which would stimulate further investments by the industry. In fact, the industrial stakeholders involved in the Impact Assessment estimated that the launch of a JTI for H & FC would increase their investments by € 600 million compared to the business as usual option which would accelerate the market breakthrough of H & FC by 2-5 years and thus lead to earlier gains on improving energy efficiency and security of supply while reducing greenhouse gases and pollution (European Commission 2007b, 3, 17-21, 41). The postulated increase of the investments of the industry resulting from the launch of a JTI was also used to underline the substantial, long-term commitment of the European industry to the development of H & FC. According to a Member of the European Parliament for instance “the private companies have always said that for each Euro public money there will be five Euro private money” (Interviewee 6, 2012).

This illustrates that the production of expertise was guided and shaped by the objective to legitimize the launch of a JTI for H & FC in FP 7. Analogous to the Snapshot 2020 objectives, the concrete numbers of increased investments of € 600 million and an accelerated development by 2-5 years in the industry submission may not have been taken too seriously by the industrial actors themselves but they did fulfil a specific function in the political discussions. These concrete numbers constitute vivid examples that could be used in the political negotiations to illustrate the advantage of a JTI over other policy instruments to policy-makers not involved in the development of H & FC. Hence the political requirements for legitimizing the launch of a JTI for H & FC determined the form of the expertise produced. The decision to launch a JTI had to be justified by concrete advantages understandable to policy-makers irrespective of their specific knowledge of H & FC.

The additional European value of a JTI for H & FC and the advantages of a JTI over existing policy instruments were also outlined by portraying H & FC as a prime example of scattered and fragmented funding in the energy, environment, and transport programmes of the FPs of the EC. Above all the supporters of H & FC in DG R&I used this fact as an argument to illustrate to their colleagues in the EC that the overall funding in the area of H & FC does not meet the challenges in the development of these technologies. One of the main points was that there is no guaranteed or fixed budget but rather H & FC project proposals have to compete with project proposals on other technologies in the funding programmes for energy, environment, transport etc. Hence it was argued that providing one single instrument for the funding of H & FC in the form of a JTI would considerably increase the impact on the development of these technologies.

However, this argument was also used by the industrial companies arguing for the launch of a JTI for H & FC. Large as well as small companies argued in common that the usual funding mechanisms of the EU will not enable a breakthrough in the commercialization of H & FC. In their view the usual funding programmes of the FPs focused too much on promoting fundamental research, while what would be needed for a commercialization of H & FC were large-scale demonstration projects. Industrial companies argued that only these large-scale demonstration projects would bring about the major impact required in the form of substantial improvements in the efficiency and reliability of H & FC. For this purpose, these actors claimed that what is needed is to test the existing H & FC technologies under real conditions in the field rather than further fundamental research in laboratories.

Based on these arguments and expertise, the policy entrepreneurs from the EC and the large private enterprises succeeded in establishing the advantages of the launch of a JTI for H & FC over existing policy instruments in the Communication on the SET Plan of the EC. In the SET Plan it is stated that some of the new energy technologies needed to achieve the EU's energy policy objectives require large-scale investments as their commercialization cannot be met by the market, by individual Member States or by the usual EU R&I approach of collaborative research. Rather, the development of these new energy technologies would require a new model of cooperation (European Commission 2007d, 6). The envisioned JTI for H & FC is stated as a prime example of this new European approach to foster innovation in energy technologies:

> "These Community programmes should be better used to catalyse the actions of Member States and the private sector, taking them to a new dimension by evolving towards a paradigm of steering and co-financing joint programmes rather than projects. This calls for a change in the way these programmes are implemented. The proposed Fuel Cell and Hydrogen Joint Technology Initiative is a prime example of such a change, with Community Research Framework Programme funding being used to co-finance a programme of research and demonstration with industry in a new, European public-private partnership." (European Commission 2007d, 8)

In sum, this subchapter has explained how the stage of policy formulation and decision-making in EU R&I policy has shaped the production of expertise on H & FC. In order to situate H & FC in FP 7, these were portrayed as new, low carbon energy technologies with the expertise required. Simultaneously, the necessary expertise to legitimize the launch of a JTI for H & FC in an Impact Assessment of the EC was developed. The subchapter will illustrate how the expertise developed was fed into the policy discourse and used to legitimize the launch of a JTI on H & FC and to defend these technologies against critique.

## 7.3 The policy discourse: Justifying the launch of a JTI for H & FC

This subchapter explains how the expertise developed was used to justify the launch of a JTI for H & FC in the broader policy discourse and in the Impact Assessment which was conducted by the EC in 2007. The broader policy discourse on H & FC took place in parallel to the conduct of the Impact Assessment and thus the arguments exchanged were partly the same as the discussions overlapped. However, while the discussions on the Impact Assessment in part also dealt with the general view on H & FC, the Impact Assessment was predominantly a technical exercise that the supporters of H & FC inside of the EC had to accomplish to demonstrate that a JTI is the most viable policy instrument for the promotion of H & FC in FP 7. In contrast, the broader policy discourse on H & FC that was also led in the EP and in the wider public was more about establishing H & FC as new, low carbon energy technologies in general.

The following four five of this subchapter will explain how the launch of a JTI for H & FC in FP 7 was justified in both the wider discourse and in the Impact Assessment with the expertise produced. First, it will be illustrated how the policy entrepreneurs from the EC and the large private companies fed the expertise produced into the policy discourse in order to gather further support for the launch of a JTI for H & FC in a broader discourse coalition. Second, the discourse coalition critical on H & FC and its main arguments will be outlined. Third, it will be described how the supporters of H & FC defended these technologies against the criticism. Fourth, it will be explained how the expertise developed was used to justify the launch of a JTI for H & FC in the Impact Assessment of the EC. Finally, it is outlined how the overall discourse on H & FC resulted in the policy output of the launch of a JTI for H & FC.

### 7.3.1 The discourse coalition for fuel cells and hydrogen as new, low carbon energy technologies

In contrast to the early years of the new century, in the time period of 2004-2008 H & FC were not a top priority on the European agenda anymore. A new college of Commissioners entered into office and the new Commissioners did not continue to actively promote the hydrogen economy as their predecessors had done. Furthermore, media coverage on H & FC was considerably reduced and only a few actors outside of the expertise discourse on H & FC continued to speak and write about these technologies. However, in spite of these drawbacks, the supporters of H & FC succeeded in advocating the storyline of fuel cells and hydrogen as new, low carbon energy technologies to the new Commissioners of Energy, Research, and Transport and in gathering further support for the launch of a JTI for H & FC.

The following paragraphs will describe this new discourse coalition supporting the storyline of fuel cells and hydrogen as new, low carbon energy technologies in more detail. First, it will be outlined how the policy entrepreneurs from the EC and the large private companies advocated fuel cells and hydrogen as new, low carbon energy technologies to the decision-makers of the EC. Second, it will be explained how further support for the launch of a JTI for H & FC in FP 7 was gathered in the different DGs of the EC and in the EP.

*Advocating H & FC as new, low carbon energy technologies to the decision-makers in the EC*

The first important event that took place at the beginning of the second stage of EU H & FC policy was the entry into office of a new college of European Commissioners in 2004. Jose Manuel Barroso succeeded Romano Prodi as the President of the Commission, Andris Piebalgs succeeded Loyola de Palacio as the Commissioner for Energy and Janez Potocnik succeeded Philippe Busquin as the Commissioner for Research. In addition, Jacques Barrot succeeded Loyola de Palacio as Commissioner for Transport as the Barroso Commission had separate Commissioner for Energy and Transport while under the Prodi Commission Loyola de Palacio was a Commissioner for both Energy and Transport. It quickly became clear that this new college of Commissioners was not as supportive of H & FC as their predecessors were.

However, the high-ranking officials in the EC and the representatives of large private enterprises arguing for the launch of a JTI for H & FC succeeded in advocating H & FC as new, low carbon energy technologies to the new Commissioners of Energy, Reseach, and Transport. This new view on H & FC is well illustrated by the speech of Janez Potocnik, the then Commissioner for Research, at the World Hydrogen Energy Conference in Lyon in 2006:

> "In short, hydrogen ticks all the right boxes in terms of the global policy benefits it can bring. It may, or may not be the "Holy Grail" for energy, but I am convinced that it will play a major role in our future energy systems. Hydrogen may be the simplest and lightest element in the Periodic Table. Paradoxically, harnessing it for everyday consumption is surely one of the toughest technical and political challenges we have faced for a long time." (European Commission 2006c)

This new view on H & FC was not only supported by the then Commissioner for Research, Janez Potocnik, but also by the then Commissioner for Energy, Andris Piebalgs, and the then Vice-President of the EC and Commissioner for Transport Jacques Barrot. Andris Piebalgs emphasized the importance of H & FC among other new energy technologies for the future energy system of the EU and the role of H & FC as one among other priorities in the energy sector in the seventh FP in many speeches (European Commission 2005b, 2006a, 2006b). Also Jacques Barrot underlined that "Hydrogen for transport is one of the elements that will make this sustainable mobility policy possible" (European Commission 2006d).

This continued support of H & FC as one among other new energy technologies at the top of the EC was partly the result of the still strong support for H & FC inside of DG R&I and DG TREN (Transport and Energy) and the JRC. There were still many officials at different hierarchical levels inside of these DGs that supported the launch of a JTI for H & FC. Above all the high-ranking supporters of H & FC inside of the EC coordinated the development of the expertise that was needed to portray H & FC as one among other low carbon energy technologies that will be needed for the future emission-free energy system of the EU as outlined in the preceding subchapter. These high-ranking officials at the Director or Director-General level also had the best access to the decision-makers in the EC and used the expertise developed to advocate the launch of a JTI for H & FC to these.

In addition to the supporters of H & FC inside of the EC, also many representatives of private enterprises and public research institutes argued for the launch of a JTI for H & FC. Above all large private enterprises such as car manufacturers, oil companies, and energy utilities not only promoted H & FC as new, low carbon energy technologies in public but also possessed the resources that granted them a good access to the top of the EC to get their voices heard. Consequently, the representatives of large private enterprises played a key role in transferring the expertise produced into the policy discourse to the new college of Commissioners.

Finally, also public research institutes and various small and medium sizes enterprises active in the area of H & FC played their role in keeping H & FC on the agenda as they not only uttered their support of these technologies in public but also as their mere involvement in the area of H & FC fitted well into the new understanding of innovation of the EC. While these public research institutes and small and medium sizes enterprises did not possess the resources to establish direct contact to the new college of Commissioners, their involvement in the development of H & FC was of importance as the EC's general approach to innovation ascribed a key role to SMEs. In addition, it was argued that a JTI for H & FC was to facilitate the involvement of SMEs in the development of H & FC more than other policy instruments.

*Gathering further support for the launch of a JTI for H & FC*

The shift from the vision of the hydrogen economy to the storyline of fuel cells and hydrogen as new, low carbon energy technologies enabled the supporters of H & FC to advocate the future potential of H & FC to the new officials of the EC. While many of the officials that have participated in setting H & FC on the European agenda in the first years of the new millennium were still supportive of H & FC, new policy and scientific officers who either recently joined the EC or who were transferred from other DGs have not been involved in setting H & FC on the agenda and also have not been involved in the development of these technologies in any way before. However, the new storyline outlining fuel cells and hydrogen as new, low carbon energy technologies enabled them to see a meaning in these technologies as part of a broader alternative energy portfolio of the EU that would be needed to establish a future sustainable energy system. Hence, in spite of the loss of supporters of H & FC due to the disappointment with the hydrogen economy and due to the emerging storyline of electric mobility, the European H & FC network could also recruit new members inside of the EC.

In addition to the EC, the private sector and public research institutes, support for the launch of a JTI for H & FC was also gathered in the EP. The former Commissioner for Research, Philippe Busquin, continued to promote H & FC after he became a MEP in 2004. Together with some other MEPs he formed a group for the promotion of H & FC. While H & FC were not discussed much in the EP, this group contributed to ensure the support of the EP which would be needed for the launch of the JTI on H & FC. The group even succeeded in convincing the Vice-President of The Greens/European Free Alliance, Claude Turmes, to join them in a written declaration for the establishment of a green hydrogen economy in the EU in spite of the party's rather critical view on H & FC (European Parliament 2007).

Another important factor in gathering support for the launch of a JTI was that the common development of expertise allowed the many supporters of H & FC in the EC, in private enterprises, and in public research institutes to speak with one voice which not only increased the validity of their expertise but also the political weight of their arguments. The policy entrepreneurs who possessed the necessary resources have guided this development of expertise and ensured the consistency of the data and the results across the different expert reports and studies as outlined in the preceding subchapter. This consistency contributed to aligning the different actors on promoting the common story line of fuel cells and hydrogen as new, low carbon energy technologies which increase the overall influence of the discourse coalition.

### 7.3.2 The discourse coalition critical of H & FC

The critique on H & FC rested on two main pillars. First, several interviews confirmed that the years of 2004-2008 saw a widespread disappointment with the vision of the hydrogen economy which had not progressed as quickly as many had hoped for or expected (Interviewee 11, 2013; Interviewee 12, 2013; Interviewee 15, 2012). Both H & FC vehicles and stationary applications were still nowhere near commercialization. The large demonstration project with fuel cell buses powered by hydrogen, CUTE, had been finished and the results were sobering as they showed that H & FC still had a long way to go and that much more technical improvement and cost reduction will be needed before H & FC vehicles actually hit the road.

Second, H & FC gained a serious competitor as the storyline of electric mobility emerged. The battery technology deemed a failure in the early 2000s by the EC made a comeback and was perceived by many as the best solution for a future sustainable mobility with battery electric vehicles. These were supposed to be more energy efficient than H & FC vehicles and thus also more ecological. Hence H & FC were not perceived as the only technology that could enable an emission-free transport system any longer. This had the effect that the performance and the potential of H & FC were compared to that of another technology.

Although one might argue that disappointment with H & FC does not have to result in support for the battery technology, in practice this very often was the case. Many previous supporters of H & FC expressed their disappointment with these technologies and pointed to the battery technology as a more efficient alternative. Therefore, the expression of disappointment with H & FC and the emphasis of the technical superiority of the battery technology will be treated as part of a broader discourse coalition critical on H & FC. Albeit there were almost no concerted actions between the different critics of H & FC, the expression of disappointment and the portrayal of batteries as the more efficient technology often went hand in hand.

The following paragraphs will first outline the unfulfilled expectations that spread as the vision of the hydrogen economy did not materialize as quickly as hoped for. Thereafter, it will be described how the storyline of electric mobility emerged from another policy subsystem but got linked to the discourse on H & FC through several key issues such as energy efficiency and sustainability.

*Unfulfilled expectations and disappointment*

The following paragraphs show that unfulfilled expectations together with new expertise can end the support of a specific storyline. The hydrogen economy did not come about as quickly as some people had hoped for in the EC. Apart from some research and demonstration projects, there were still no fuel cell vehicles or hydrogen filling stations anywhere to be seen and it became apparent that this would not be the case in the following years either. The large European car manufacturers had publicly announced that they would not start mass production of fuel cell vehicles until the second decade of the century. The hydrogen economy seemed farther away than many had thought of.

This impression was further underpinned by hard technical facts. CUTE, the large EU demonstration project with 27 hydrogen powered fuel cell buses, was launched in 2001 and ended in 2005 (CUTE 2006, 8). The results of the CUTE project showed that a commercialization of H & FC would still require significant technological progress in terms of reducing the costs of fuel cells, increasing the durability of fuel cells, improving power density and high voltage components, and improving hydrogen refuelling technologies (CUTE 2006, 98, 103). Some officials in the EC who had been involved in setting the hydrogen economy on the European agenda perceived these outcomes of the CUTE project as rather sobering.

Consequently, this widely perceived disappointment with the slow progress of the hydrogen economy cost H & FC some of its previous supporters in the EC. A certain number of EC officials became sceptical and lost their belief in the hydrogen economy. They also lost their trust in the promises put forward by the car manufacturers as these had been claiming to bring H & FC to the markets for years and still nothing had happened. The delays of the commercialization into the next decade were not believed to bring about the actual commercialization of H & FC but rather were believed to be followed by further delays.

The widespread disappointment resulted in a reduced support of H & FC inside the EC in two ways. First, some of the previous supporters of the hydrogen economy had turned their back towards H & FC and became rather critical towards further investments of public money into these technologies. Second, the broad support that the hydrogen economy received around the turn of the century caused many persons that were neither for nor against the hydrogen economy to just accept the EC's support of it as there was no wider critical discourse which could have provided them with sound arguments against H & FC. This made it easier to just accept the storyline of the hydrogen economy than to raise critical views on it. However, now that there was some critique on H & FC inside the EC further persons could articulate their scepticism.

The disappointment hit hydrogen stronger than fuel cells. Some officials of the EC had very negative associations with hydrogen as the vision of the hydrogen economy did not materialize as quickly as hoped for. One of their arguments was for instance that the built-up of a hydrogen infrastructure was too expensive. Fuel cells, however, were still perceived as an efficient energy technology with a good perspective as fuel cells could be powered by a wide range of different fuels and hence did not rely on the production of hydrogen. This positive assessment counted above all for fuel cell types used for stationary applications such as phosphoric acid (hereinafter PAFC), molten carbonate (hereinafter MCFC) and solid oxide fuel cells (hereinafter SOFC), while the future of proton exchange membrane fuel cells (hereinafter PEFC) that were supposed to be powered by hydrogen for transport applications was less optimistically assessed due to their linkage to hydrogen.

One of the persons that uttered this view was for instance Ulf Bossel, the then CEO of the SME Almus AG that develops products based on solid oxide fuel cell technology. Ulf Bossel was also the founder and organizer of the annual European Fuel Cell Forum which each year takes place in Lucerne, Switzerland, and serves as a platform for the exchange of information on H & FC for all actors with an interest in these technologies (European Fuel Cell Forum 2014). The European Fuel Cell Forum held in 2012 for instance attracted a wide range of different actors of the European H & FC community (European Fuel Cell Forum 2012). The following quotation of Ulf Bossel exemplifies how the critique raised in the years of 2004-2008 was mainly directed at hydrogen, while fuel cells were still perceived an efficient energy technology that could be powered with different fuels other than hydrogen:

> "The impressive performance of phosphoric acid, molten carbonate and solid oxide fuel cells clearly indicates that these fuel cell families can meet the challenges of a sustainable future. Some of these fuel cells have reached 65,000 hours of operation with the first stack and natural gas or bio-methane. It is highly uncertain that synthetic hydrogen can ever be established as a universal energy carrier. …
>
> A wasteful hydrogen economy does not meet the criteria of sustainability. As a result, a viable free-market hydrogen infrastructure will never be established and fuel cells for hydrogen may not be needed. …
>
> Therefore, the schedule of the European SOFC Forum will be continued in 2008 with an extended conference every second year. Beginning 2007 (July 2 to 6) sustainable energy topics will be emphasized in odd years. Despite earlier announcements the European PEFC Forum series will not be continued. I would like to thank all who have contributed to establish the European PEFC Forum. You and your colleagues have developed a magnificent technology, but the fuel needed to make it work is not offered

> by nature. We cannot solve the energy problem by wasting energy. The laws of physics speak against a hydrogen economy." (Bossel 2007)

This quotation shows how new expertise on the efficiency of hydrogen production has been developed and fed into the policy subsystem on H & FC where it changed the perception of hydrogen of some persons inside the EC. Even inside of DG R&I, in which H & FC had most of their supporters, some policy and scientific officers became sceptical on hydrogen and proton exchange membrane fuel cells, while they still saw a potential future for stationary fuel cell types such as PAFC, SOFC and MCFC. This loss of some supporters was to affect the further development of EU H & FC policy. The disappointment with the hydrogen economy has made some persons inside of the EC sceptical on the future outlook of H & FC. These people would have to be persuaded to agree to the launch of a Joint Technology Initiative for H & FC which caused more controversial discussions inside of the EC than the launch of the HLG and the HFP.

*Electric mobility*

The storyline of electric mobility emerged from the evolving policy subsystem on the battery technology in the years from 2005-2007. After large field trials with battery electric vehicles have been performed all over the world in the early 1990s (Fogelberg 2000, 1), a certain disappointment gained ground in the late 1990s and early 2000s due to the sobering results. In fact, the EC did not regard battery electric vehicles as a promising option to achieve sustainable mobility in the early 2000s but only conceived of them as viable for niche markets (European Commission 2001b, 10). A broader market breakthrough was supposed to be impeded through the short range of battery electric vehicles caused by the limited energy storage capacity of the batteries (European Commission 2001b, 11).

However, in the years from 2005-2007 new expectations on technical breakthroughs in the battery technology arose, promising considerably increased ranges of battery electric vehicles. According to the storyline of electric mobility batteries were supposed to be charged with electricity that was produced from renewable energies. Hence batteries could be used to deliver electricity for vehicle propulsion in transport applications where they would replace the internal combustion engine. This entire energy cycle from battery charging to vehicle propulsion was supposed to not cause any emissions provided that the electricity was generated from renewable energy sources.

Hence the storyline of electric mobility made similar promises as that of the hydrogen economy in terms of enabling a sustainable and emission-free mobility. Many supporters of the storyline of electric mobility argued that the battery technology is superior to H & FC highlighting above all the issue of energy efficiency. Their main argument was that the entire energy cycle from hydrogen production to its use in fuel cells for electricity generation causes high losses of energy. First, the production of hydrogen by renewable energy sources causes losses; thereafter the compression or liquefaction of hydrogen into a gaseous or a liquid fuel would cause further losses; then the compressed or liquefied hydrogen would have to be distributed and stored which would cause further energy losses until finally the hydrogen could be converted back into electricity by fuel cells which again would cause energy losses. This energy cycle was compared to that of the battery electric vehicle as illustrated by the figure below:

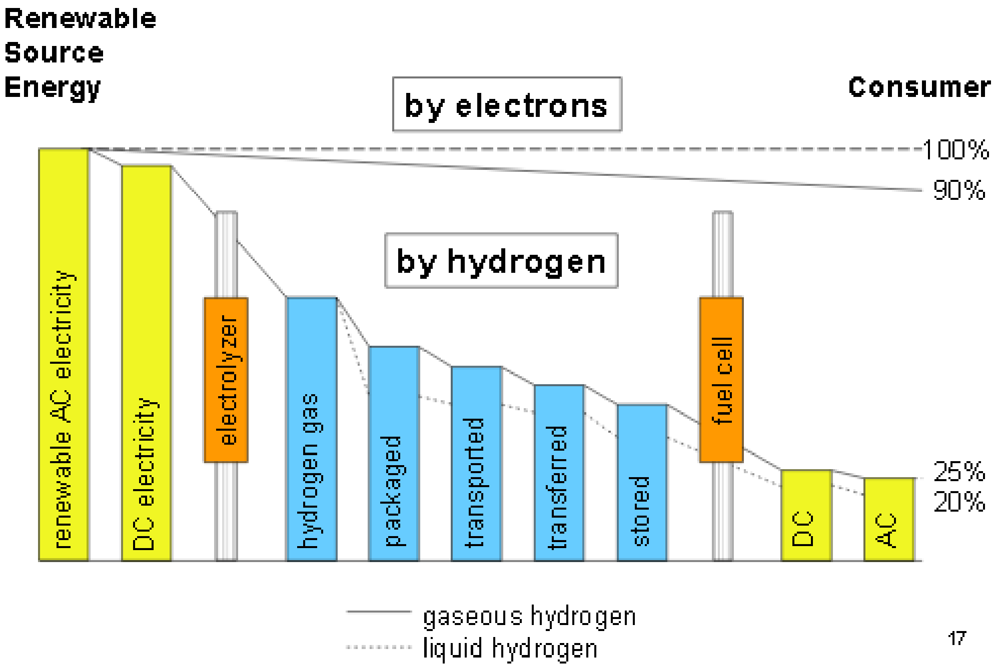



**Figure 13**, Comparison of the efficiency rates for electricity- and hydrogen-based energy cycles

Source: (Bossel 2005, 12)

The figure shows a clear picture: While electricity production from renewable energies and its direct distribution over a modern power grid could bring 90% of the initial energy input to the consumer, the hydrogen energy cycle could only deliver 20-25% of the initial energy input to the consumer. Due to these immense energy losses in the hydrogen energy cycle, it was argued that batteries constitute the best technology to achieve a sustainable and emission-free mobility, while other technologies such as heat pumps and pumped-storage hydroelectricity were the preferred solutions for stationary electricity and heat generation in residential or industrial buildings.

These efficiency rates were picked up by some officials in the EC and by some Members of the EP in their line of argumentation against H & FC. The following quotation of a MEP provides a prime example of the critique articulated on the inefficiency of H & FC:

> "Hydrogen, except of some niche markets, is complete nonsense for the energy system due to its high energy losses. Hydrogen via electrolysis means that if you produce hydrogen directly from a nuclear power plant, you have a conversion rate of 1:3 to produce electricity and then you can convert 1/5 of this electricity into hydrogen which results in a conversion rate of 1:15 and then when you have the hydrogen you have further losses when you convert it back to electricity. But when you generate electricity and use it directly you do not have all these losses. Therefore, scientists that do not work for someone who pursues a hidden agenda have a very, very sobering view on hydrogen production." (Interviewee 6, 2012)

Hence the development of new expertise on the future potential of the battery technology triggered further critique of the hydrogen economy as it highlighted another technology that promised to serve the same purposes as H & FC but in a much more energy efficient way. This constituted a significant difference to the first years of the new millennium in which many officials in the EC perceived H & FC as the only viable technology to bring about a sustainable and emission-free transport system in the future. The new expertise on the future potential of the battery technology, however, challenged this view of H & FC being the best option available to achieve an emission-free transport system in the future. This demanded of the supporters of H & FC to defend these technologies against this critique in order to legitimize the launch of a Joint Technology Initiative for H & FC as will be outlined in the following subchapter.

### 7.3.3 Defending H & FC against the critique

The discourse coalition for fuel cells and hydrogen as new, low carbon energy technologies reacted to the critique on H & FC and defended these technologies by various arguments. The supporters of H & FC highlighted for instance that there are cheap ways to introduce hydrogen into the transport sector at the beginning. It was illustrated that hydrogen is a byproduct of many industries which is in most cases combusted as a substitute for natural gas but which could as well be used as a fuel for fuel cell vehicles. Hence it was argued that this hydrogen could be used to introduce a certain amount of hydrogen in the transport sector in a cheap way as it is generated as a by-product anyway.

It was also attempted to bring H & FC under the emerging storyline of electric mobility. The main argument was that both fuel cells and batteries provide electricity for the movement of the vehicle and thus both technologies allow for an electrification of the drivetrain. Fuel cells, of course, first have to generate this electricity onboard from hydrogen, while batteries can be directly charged with electricity from the grid. However, the supporters of H & FC emphasized that where the electricity comes from is of secondary importance as long as the technology provides for an electrification of the drivetrain as the following quotation of an official of the national German administration exemplifies:

> "I think it is weird that some try to portray a competitive relation between a battery electric vehicle and a vehicle with a fuel cell. What is important is the switch from a combustion engine to an electric drivetrain, that is the important step, that there is a combustion engine in one car and an electric drivetrain in another one. Where the electricity that moves the car comes from in the end, whether from a battery or from a fuel cell, that is of secondary importance. … Eventually what matters is the electric vehicle and it makes sense to develop both technologies in parallel." (Interviewee 6, 2011)

In fact, right from the start many supporters of H & FC argued for a complementary relationship between the two technologies. These actors acknowledged the high efficiency rates of batteries but also pointed out that H & FC vehicles could achieve by far longer ranges and could be refuelled much quicker than batteries could be recharged so that batteries and H & FC would target different segments of the car market. One of the main arguments was that battery electric vehicles would for a long time be limited to a range of around 150-200 km, while H & FC vehicles promised to reach a range of 500 km in the short term. Furthermore, it was argued that it would only take a few minutes to refuel the hydrogen tank of a fuel cell vehicle, while recharging the battery of a battery electric vehicle could take up to several hours depending on the size and the capacity of the battery. Therefore, battery electric vehicles were to be viable for small vehicles used for short distances in cities, while only H & FC vehicles could serve for medium and long range distances.

In addition, the supporters of H & FC highlighted that in some cases both technologies could be applied in one and the same vehicle and fulfil complementary functions. In the view of these actors H & FC vehicles and battery electric vehicles would not only serve different segments of the car market such as small, short range city-vehicles and larger vehicles for longer ranges but also both technologies could be combined in one and the same vehicle in many ways. Both batteries and fuel cells could for instance be used as a range extender while the respective other technology serves as the main propulsion system. Hybrid concepts of batteries and fuel cells are conceivable in many ways as the following quotation of a scientist of a public research institute illustrates:

> "Of course I also see a complementary relationship between batteries and fuel cells. There is not only one solution, there are many solutions. You could have two extreme solutions, the two extremes are: pure battery and pure fuel cell. But between them you could have hybridization at different degrees, you could have half half, you could have 20% and depending on the market, on the country, on the application, you could have some hybrid system." (Interviewee 8, 2012)

In fact, many public research institutes and large car manufacturing companies work on both technologies. While Daimler's focus is on the development of fuel cell vehicles, it also develops battery electric vehicles such as the Smart Fortwo Electric Drive. In a similar vein, just the other way around, Renault and Peugeot focus on the development of battery electric vehicles but nevertheless they invest in fuel cell development as well. Also many public research institutes and universities often have units doing research on both batteries and H &

FC as the following quotations of a scientist of the JRC and of a scientist of a public research institute illustrate:

> „In my unit we deal with both battery and H & FC technology, we test both. … So it speaks for itself if I have to do with electrochemical devices which is a fuel cell and I have to do with an electrochemical conversion device which is a battery, both are electrochemical conversion devices so for both I need electrochemists to do the work and to do the research that we are doing. So are we discussing the pros and cons of the individual technologies within our group? Not so much." (Interviewee 9, 2013)

> "Everywhere in the laboratories, more and more they have to find the money outside and it's a lot of effort and of course the funding rate is important because if you make a lot of effort to have only a funding rate of 20%, its not worth it. And in the same time, most of research laboratories are working on a different topic, not only fuel cell, they are working also, most of them on batteries, on different topics, and of course the main public laboratories in most of cases are choosing the easiest way to get money. Its not by principle we work on fuel cells because it's a marvelous topic, because I see in my institute, if the battery topic is very well funded, maybe we want to shift a little towards battery." (Interviewee 8, 2012)

Hence the main argument of the discourse coalition for fuel cells and hydrogen as new, low carbon energy technologies was not to deny the higher efficiency rates of battery electric vehicles but rather to portray a complementary relationship between the two technologies. In fact, they argued that both technologies will be needed in order to achieve an emission-free transport sector as they will serve different segments of the car market. This proved to be sufficient for the launch of a JTI as it did not have to be demonstrated that H & FC are superior to the battery technology but rather that H & FC constitute one among other new, low carbon energy technologies that might play an important role in achieving an emission-free energy and transport system in the future.

### 7.3.4 Proving the need of a JTI with the expertise produced: The Impact Assessment

This subchapter explains how the expertise produced on H & FC was used to demonstrate the need of a JTI in an Impact Assessment (hereinafter IA) conducted by the EC in 2007. The IA is a formal requirement of the EC that has to be conducted in order to prove that a JTI is the most viable policy instrument to be applied to the case in question. For this purpose, the policy entrepreneurs, who previously had guided the production of expertise, employed this expertise to advocate the launch a JTI for H & FC in FP 7 to other officials in the EC who were not involved in the expertise discourse on H & FC. First, the concrete data on the future performance of H & FC were used to illustrate that these technologies can contribute to the achievement of the broader EU policy objectives in the future. Second, the expertise was used to outline that a JTI is the most viable policy instrument to promote the development of H & FC towards the achievement of these objectives.

Hence the IA can be described as a formal process that served the purpose of illustrating to the relevant EC officials involved in the preparation of FP 7 that H & FC should be one of the technologies that should be promoted and of a JTI being the appropriate policy instrument for this promotion. To explain this process in more detail this subchapter first outlines the general guidelines for the Impact Assessments of the EC in order to enhance the reader’s understanding of the formal regulations for this procedure. Thereafter, it is illustrated how the supporters of H & FC applied the expertise developed in the H & FC projects funded by the EC in FP 6 to demonstrate to that the launch of a JTI for H & FC is the best policy option available for the promotion of these technologies in FP 7.

*The general guidelines for the Impact Assessments of the EC*

The main idea behind the IAs of the EC is to give decision-makers evidence on the advantages and disadvantages of a policy proposal. IAs are to explain “why action should be taken at EU level and why the proposed response is appropriate” (European Commission 2014f). The current EU Impact Assessment regulations have been initiated by the Gothenburg (June 2001) and the Laeken (December 2001) European Councils (European Commission 2014a). The intention behind IAs was to consider the effects of policy proposals in their economic, social and environmental dimensions and to simplify and improve the regulatory environment in the EU (European Commission 2014a). Consequently, the EC published a Communication on the general simplification and improvement of the regulatory environment (European Commission 2002a) and two Communications on the introduction of a formal IA procedure (European Commission 2002b) and on the general principles and minimum standards for the consultation of interested parties (European Commission 2002c).

The performance of an IA is a rather formalized procedure with detailed guidelines provided for every single step involved. The DG, which is developing the policy proposal that the IA is to assess, is also in charge of carrying out the IA (European Commission 2008a, 3, 4). It first has to develop a time schedule for the IA and to set up steering group including representatives from all relevant EC services that can provide advice during the performance of the IA. Thereafter, interested parties should be consulted and the expertise required should be collected before the actual IA analysis can be conducted (European Commission 2008a, 5). The first draft of the IA report is to be submitted to the EC’s Impact Assessment Board which is composed of high-ranking officials of the EC that examine and issue opinions on any IA conducted by the services of the EC (European Commission 2014e). Finally, the final version of the IA report has to be developed on the basis of the recommendations of the Impact Assessment Board (European Commission 2008a, 5).

The guidelines of the EC distinguish among six key analytical steps that have to be performed for each IA: 1) Problem identification, 2) Objective of the proposal, 3) Policy options, 4) Analysis of the impacts, 5) Comparison of the policy options, and 6) Policy monitoring and evaluation (European Commission 2002b, 12, 2008a, 21). First, the problem that is to be tackled by the policy proposal is to be outlined before the corresponding objectives for tackling the problem are to be explained. Thereafter, the main policy options available are illustrated and the potential impacts of each policy option are analyzed and compared to each other. Finally, it is to be outlined how the progress in achieving the policy objectives is to be monitored and evaluated (European Commission 2002b, 12, 2008a, 21).

*Demonstrating that the launch of a JTI is the best policy option for the promotion of H & FC*

The conduct of the IA was mainly driven by the EC officials and the large industrial companies supportive of H & FC who advocated the launch of a JTI for H & FC to further officials in different DGs of the EC. Most of the EC officials supportive of H & FC came from DG R&I, DG TREN, and the JRC and they have already been involved in the development of a European H & FC policy since the turn of the century. In order to justify the launch of a JTI the supporters of H & FC not only had to the advocate the future potential of these technologies to other officials in DG R&I and DG TREN, who were not involved in the development of H & FC, but also to the officials of many other DGs. The steering group of the IA for instance comprised officials from 12 different DGs of the EC. It was formed in May 2007 to review and to comment on the different drafts of the IA report developed before the publication of the final version (European Commission 2007b, 5).

For this purpose, the potential of H & FC to contribute to the achievement of the general EU energy and R&I policy objectives such as the security of energy supply, emission reduction, energy efficiency, sustainable mobility, and industrial competitiveness was underpinned by the technical expertise developed in several reports and studies such as the Implementation Plan of the HFP, the HyWays report, the HyLights report, the Roads2Hycom report, the WETO-H2 study, and the EUCAR/CONCAWE/JRC study (European Commission 2007b, 5, 10, 11). In addition, more specific objectives for the development of H & FC which are to be achieved through the launch of a JTI were outlined. These specific objectives included, among others, enabling the market breakthrough of H & FC, placing the EU at the forefront of the global development of H & FC, reaching the critical mass of research efforts required, building the European Research Area in H & FC through close cooperation with research carried out at national and regional levels, and encouraging the participation of new Member States. Finally, the snapshot 2020 targets from the Implementation Plan of the HFP were stated as concrete technical objectives for the development of H & FC (European Commission 2007b, 15, 16).

Also the assessment of the three policy options chosen for comparison, 1) Inter-governmental programme of research established under Article 169, 2) Business-as-usual: Seventh Framework Programme plus national and regional effort, supported by a Technology Platform to provide strategic direction, and 3) Establishment of a Joint Technology Initiative as a Joint Undertaking under Article 171, was carried out by the expertise developed with the private companies and the public research institutes. The option of an inter-governmental programme for instance was not considered further due to the lack of the support of industrial stakeholders whose main argument was that annual budgetary decisions in the Member States and long consultations would result in a slow decision-making process while the development of H & FC would require an industry-led programme that is focused on solving technical issues in the most cost-effective way (European Commission 2007b, 17).

Hence two policy options remained for a closer comparison with each other: The usual approach of collaborative research under FP 7 and the launch of a JTI for H & FC. While it is acknowledged that the positive effects of H & FC with regard to the longer-term economic, environmental, and social impacts would eventually by realized through both policy options, the main arguments for the launch of a JTI were that it would reduce the time of achieving these objectives and the risk of not achieving them (European Commission 2007b, 29-39). Furthermore, it was argued that the business as usual scenario would have the disadvantages of the fragmentation of funding across different programmes of the FP, the lack of a continuous strategy and a fixed budget over several years, high administrative costs and no leading role for the industry (European Commission 2007b, 17, 18). In contrast, the launch of a JTI was to have advantages based on the specific structure of a JTI such as, among others, the ensured inclusion of SMEs into the development of H & FC (European Commission 2007b, 27).

Consequently, the launch of a JTI was a portrayed as the most viable policy option to achieve the future potential of H & FC as new, low carbon energy technologies in the Impact Assessment.

### 7.3.5 The policy output: The launch of a JTI for fuel cells and hydrogen

The discourse coalition promoting a JTI for H & FC succeeded in asserting their view on fuel cells and hydrogen as one among other new, low carbon energy technologies required to achieve the broader energy and R&I policy objectives of the EC. In spite of the disappointment with the progress of the hydrogen economy and the emerging storyline of electric mobility, the decision-makers in the EC supported the launch of a JTI for H & FC in FP 7. This was mainly the achievement of the high-ranking officials in DG R&I and DG TREN and the representatives of large private companies who had good access to the decision-makers in the EC and who used the expertise developed to advocate the promotion of H & FC as one among other new, low carbon energy technologies in FP 7. In addition, these policy entrepreneurs defended H & FC against the critique from the EC officials disappointed with the slow progress of the hydrogen economy and the critique from the supporters of the battery technology.

As a result, the EC published its proposal to set up the Fuel Cell & Hydrogen Joint Undertaking (hereinafter FCH JU) as a legal entity under Article 171 of the Treaty establishing the European Community on 9th October 2007 (European Commission 2007f, 8). The proposal was developed in parallel to the Impact Assessment and the reasons stated for the launch of the FCH JU are largely based on the IA. Hence fuel cells and hydrogen are presented as new, low carbon energy technologies and embedded in the overall EU energy and research policy objectives. Furthermore, it is argued that the EU is lagging behind the USA and Japan in the development of H & FC and that the launch of the FCH JU could reduce the time until the commercialization of H & FC by 2-5 years and increase private investments in these technologies by € 600 million (European Commission 2007f, 2-8).

However, in contrast to the IA, the proposal for the launch of the FCH JU also included the financial contribution of the European Community suggested as well as the legal text of the regulation that should be adopted by the Council and that included an annex with the statutes and the legislative financial statement proposed for the FCH JU (European Commission 2007f, 9-51). The financial contribution of the European Community to the budget of the FCH JU amounted to € 470 million. This contribution was to come from six different Directorates in two different DGs: 1) Directorate Energy, 2) Directorate Nanotechnologies, Materials, and New Production Technologies, 3) Directorate Transport, and 4) Directorate Environment from DG R&I, and 5) Directorate Energy and 6) Directorate Transport from then DG TREN (European Commission 2007f, 40). In 2010, however, DG TREN was split into DG ENER and DG MOVE so that from then onwards three different DGs from the EC contribute financially to the FCH JU. These Directorates and DGs have financially contributed to the FCH JU because they have already funded H & FC projects in previous FPs.

This financial contribution € 470 million was gave rise to controversy in the EC and above all in DG R&I. The supporters of H & FC inside of the EC and from the industry argued for a much higher contribution referring to the € 7.4 billion required according to the Implementation Plan developed by the HFP. However, H & FC had to compete with other technologies for a share of the overall financial amount available under FP 7 and other technologies had their supporters in the EC and in large industrial companies as well so that many different actors tried to secure a high amount as possible for their technological area of interest. As a result of the allegedly low budget of the FCH JU, some private enterprises quit their European H & FC activities and focused on the development of H & FC in other countries after the budget of the FCH JU was set.

## 7.4 Conclusions

The subchapters above have explained the co-production of EU H & FC policy and expertise in the years of 2004-2008 from the research perspective applied in this thesis. The main claim put forward was that the co-production of EU H & FC policy and expertise at this period in time was most influenced by the stages of policy formulation and decision-making of the wider EU R&I policy as these defined the role of expertise in the policy process. The EC was preparing its seventh FP and discussing what technological areas were to be promoted by what policy instruments. This required the formulation of concrete development programmes for the technologies to be promoted in FP 7 and the legitimization of these programmes through highlighting the future potential of these technologies.

Based on the empirical data collected for this thesis it has been illustrated how the co-production of policy and expertise was embedded in these dynamics of the stages of policy formulation and decision-making of the wider EU R&I policy. Expertise was produced in order to situate H & FC in the seventh FP of the EC and to demonstrate that a JTI is the best policy option available for the promotion of H & FC. It has been shown that the launch of a JTI required the formulation of a concrete H & FC development programme, including the definition of different technologies areas and technical objectives, and the development of expertise to underpin the future potential of H & FC as new, low carbon energy technologies. In other words, expertise was produced in order to legitimize a political decision which had to be taken at that time as part of the broader preparations of FP 7 in which the EC had to decide what technologies are to be promoted by what policy instruments.

However, the interpretation of the empirical data underlying this thesis has also shown that the influence on the co-production of policy and expertise varied considerably among the supporters of H & FC depending on the resources available to them. In the end it was high-ranking officials at the Director and Director-General levels in DG R&I and DG TREN of the EC as well as the representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities who had most influence upon the production of expertise. Due to their resources in the form of time, hierarchical position, and financial means, these actors could assert their views on H & FC and influence the production of expertise towards the achievement of their political objective of the launch a JTI for H & FC. In contrast, the public research institutes, the NGOs, and the smaller companies who were also involved in the expertise discourse on H & FC only played minor roles in the production of expertise due to the lack of the resources required to assert their views.

In addition to the resources available to them, the leading role of the representatives of large private enterprises in the production of expertise on H & FC was also supported by the way in which the policy instrument of Technology Platforms was set-up and implemented by the EC. Technology Platforms were to be driven by key industrial concerns so that the industrial actors involved should assume leading positions in their development. Consequently, the officials of the EC supported the representatives of large private enterprises in defining the concrete development programme for H & FC in the Hydrogen and Fuel Cell Technology Platform. Hence the set-up and the implementation of TPs reflects the general understanding of innovation of many officials of the EC at that time who primarily regarded innovation as the development of new commercial products. This understanding of innovation benefitted the large private enterprises as mainly these possessed the financial means required to develop new commercial products in the area of H & FC.

Their resources in the form of time, hierarchical position, and financial means also enabled the policy entrepreneurs of the EC and the large private enterprises to transfer the expertise produced into the policy discourse and to use it to gather support for the launch of a JTI in the different DGs of the EC. Due to their resources the high-ranking officials at the Director and Director-General levels in of the EC as well as the representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities had direct access to the decision-makers in the EC which allowed them to advocate the launch of a JTI for H & FC on the basis of the expertise produced. In addition, these policy entrepreneurs defended H & FC against the critique from the EC officials disappointed with the slow progress of the hydrogen economy and against the critique from the supporters of the battery technology.

As a result of this second stage in the co-production of policy and expertise the EC published its proposal on the launch of a JTI for H & FC in October 2007. In this proposal the EC argued that the JTI should be implemented by the Fuel Cell and Hydrogen Joint Undertaking which should be established as a legal entity in Brussels according to the legislation of the European Community. The decision of the Council of the EU to adopt this proposal on 30 May 2008 marks the beginning of the next stage in EU H & FC policy which will be illustrated in the following chapter: The implementation and the evaluation of the Fuel Cell and Hydrogen Joint Undertaking.

# 8 2007 - 2011: The implementation and the evaluation of the Fuel Cell & Hydrogen Joint Undertaking

This chapter explains the period of time in the years of 2007-2011 which was categorized as the third stage in the co-production of EU H & FC policy for heuristic purposes. According to the empirical data underlying this thesis, this period in time was most shaped by the stages of implementation and evaluation of the policy cycle model. Thus the research perspective of this thesis suggests that the implementation and the first interim evaluation of the Fuel Cell & Hydrogen Joint Undertaking (hereinafter FCH JU) have been most influenced by the stages of implementation and evaluation of the wider EU R&I policy. This interpretation is supported by the empirical data collected for this thesis as will be demonstrated throughout this chapter.

The implementation of the FCH JU was characterized by the distribution of the resources that have become available through its set-up. While many different actors had jointly argued for setting H & FC on the agenda and for launching a JTI for H & FC, the implementation of the FCH JU induced competition for influence and power among these actors. The officials of the EC had for instance different views on what governance structure would be best suited for the FCH JU than the representatives of the private enterprises involved. In addition, the different private enterprises and public research institutions competed with each other for securing the highest amount possible of the budget of the FCH JU for their technological area of interest in H & FC. For this purpose, all of the actors involved used specific expertise in order to highlight the importance of their technological area of interest for the overall development of H & FC.

In contrast, the first interim evaluation of the FCH JU was characterized by the bureaucratic logics of the EC as a public administration which needed results that could be used for internal, bureaucratic purposes and in the further course of the policy process. For this purpose, the independent, external experts that conducted the evaluations of the different JTIs had to apply similar criteria in their evaluations so that the results produced would allow the officials of the EC to compare the assessment of the different JTIs to each other and to use the evaluation results to illustrate the performance of the different JTIs to other EC officials who are not involved in EU R&I policy. Furthermore, the experts conducting the evaluations were asked to make recommendations for the improvement of the operation of the JTIs which the officials of the EC could refer to and implement in the further course of the policy process.

This subchapter is split into four parts to explain the implementation and the first interim evaluation of the FCH JU in more detail. First, it is explained that both the implementation and the first interim evaluation of the FCH JU were embedded in the stages of implementation and evaluation of the wider EU R&I policy. Second, the main issues of the implementation of the FCH JU will be illustrated. Third, the conduct of the first interim evaluation of the FCH JU will be outlined. Finally, the main insights of this chapter are summed up.

## 8.1 The implementations and the first interim evaluations of the Joint Technology Initiatives launched in FP 7

This subchapter explains why the period in time of 2007-2011 was categorized as the third stage in the co-production of EU H & FC policy and expertise. For this purpose, it is illustrated how the implementation and the first interim evaluation of the FCH JU was embedded in the stages of implementation and evaluation of the wider EU R&I policy and shaped by the general dynamics of these two policy cycles. The EC had decided to convert five of its twenty Technology Platforms of FP 6 into Joint Technology Initiatives in FP 7 (European Commission 2007c, 4, 2012a). In contrast to the TPs of FP 6 that were supposed to gather a wide range of different actors in specific technological areas in order to formulate concrete development programmes, the JTIs of FP 7 were to implement these development programmes and were therefore designed as legal entities equipped with their own budget. Hence the JTIs of FP 7 constituted full public-private partnerships between the EC and the industry associations in the technological areas in question. The financial contribution of the European Community to the budget of the five JTI ranges from € 0.4 – 1.0 billion (JTI Sherpas' Group 2010, 27–31).

The implementations of the different JTIs were characterized by the same dynamics as similar tasks had to be accomplished. For each JTI for instance a formal governance structure defining the decision-making bodies and the advisory bodies of the public-private partnership had to be negotiated. This was due to the EC's general regulations for JTIs which deliberately kept the specifications of the governance structure rather flexible so that these could be adjusted to the specific technical requirements and actor constellations prevailing in the case in question (European Commission 2005a, 18). In addition to the development of a formal governance structure the actors driving the different JTIs also had to further refine the development programmes of the TPs and to distribute the budget available. The distribution of the budget required not only decisions about what amounts are to be dedicated to what specific technological areas but also the development of general rules regulating how it is to be decided what research projects are to be funded and what not.

In the case of the JTI for H & FC these general tasks were accomplished in the project "Preparatory activities of the joint technology initiative for fuel cell and hydrogen" (hereinafter FCHInStruct) which was led by industrial companies and funded by the EC under the seventh FP (European Commission 2012b). FCHInStruct was officially established on October 1st 2007 and ended by December 2008 (NEW Industry Grouping 2008, 9). All the key documents defining the formal governance structure of the FCH JU, distributing the budget among the different technological areas, and defining the general rules for the selection of project proposals for funding have been developed in the FCHInStruct project as will be illustrated in more detail in the next subchapter. Hence the main task of the FCHInStruct project was to define how exactly the JTI for H & FC was to be implemented.

The documents developed in FCHInStruct indicate that a good part of the implementation of the JTIs in FP 7 was about administrative, legal, and practical issues. The establishment of the public-private partnerships as fully autonomous, legal entities required for instance the recruitment of staff for these organizations. Furthermore, of course, this staff needed premises and IT equipment and it had to develop working routines and practices for the implementation of the formal structure and the formal rules that should regulate the operations of the JTIs. In fact, these processes constituted one of the major difficulties in the implementation of the different JTIs and the aim to establish fully autonomous organizations that do not rely on the support of the officials of the EC for carrying out their tasks became one of the key objectives of the EC. Eventually, it took two to three years before all of the JTIs were considered as fully autonomous by the EC (JTI Sherpas' Group 2010, 2, 5, 8, 20).

Thus the different JTIs had only just become fully autonomous when they underwent interim evaluations that were carried out by independent experts at midterm of FP 7 in the years 2010 and 2011. These interim evaluations assessed the implementation of the different JTIs and provided recommendations for the improvement of their operation. The officials of the EC ensured that these evaluations focused on similar issues so that they produced general results of the implementation of the different JTIs which could be compared to each other. After the evaluations the JTIs were reformed on the basis of the recommendations made by the independent experts to improve their operation.

The co-production of EU H & FC policy and expertise was fully embedded in these broader dynamics of the new EU R&I policy in the years of 2007-2011 as the following two subchapters will explain in more detail. First, the implementation of JTI for H & FC will be described including all the tasks that had to be accomplished, the regulations that had to be developed as well as their application and the problems encountered. Second, the interim evaluation of the implementation of the JTI for H & FC including the selection of the independent experts and the development of the main results and recommendations is explained. Finally, the last subchapter sums up the main insights of this third stage in the co-production of EU H & FC policy and expertise.

## 8.2 The implementation of the Fuel Cell & Hydrogen Joint Undertaking

This subchapter explains the implementation of the FCH JU and illustrates by the empirical data collected that the general logics characterizing the policy stage of implementation have induced competition for influence and power among the different actors involved in the implementation of the FCH JU. While these actors mostly cooperated in the stages of agenda-setting, policy formulation, and decision-making and argued in common for setting H & FC on the European agenda and for launching the JTI for H & FC, the implementation of the FCH JU was characterized by each of them trying to assert his or her specific views and objectives which often differed from each other. As in the preceding policy stages, however, resources should still play an important role so that high-ranking officials of the EC and the representatives of large industrial enterprises remained the leading actors in the implementation of the FCH JU.

This illustrates how the analytical approach of the policy cycle model helps to interpret the actor behaviour in the expertise discourse on H & FC. All actors shared the objective of increasing the political attention and resources dedicated to the area of H & FC which facilitated the common production of expertise portraying H & FC as promising technologies of the future. However, once these recourses became available for distribution among the actors of the expertise discourse on H & FC, each of these argued on his or her own in the pursuit of financial resources and influence in the development of H & FC. For this purpose, all of the actors involved used specific arguments and expertise to assert their points of view on H & FC and to increase their role in the implementation of the FCH JU. Hence the stage of implementation in EU H & FC policy triggered the instrumental use of expertise on H & FC for securing individual benefits.

In fact, these dynamics have characterized almost all of the most important issues in the implementation of the FCH JU as will be outlined in the following seven parts of this subchapter. First, it is illustrated how this formal governance structure of the FCH JU was negotiated between the officials of the EC and the representatives of industrial companies. Second, it is explained how the overall budget of the FCH JU for the years of 2008-2013 was distributed among the different technological areas and the types of research to be pursued in them in the Multi Annual Implementation Plan. Third, it is highlighted how this distribution of the budget is further concretized each year in the Annual Implementation Plans. Fourth, the general procedure for the selection of project proposals for funding is explained. Fifth, the decision-making process of the Governing Board of the FCH JU is outlined. Sixth, the role of the two advisory bodies, the States Representatives Group and the Scientific Committee, as well as the importance of national and regional H & FC programmes for the overall governance of the FCH JU is illustrated. Finally, the main problems perceived by the actors involved in the implementation of the FCH JU are explained.

### 8.2.1 The negotiation of the formal governance structure of the Fuel Cell & Hydrogen Joint Undertaking

This subchapter explains how the formal governance structure of the FCH JU was mainly developed by the officials of the EC and the representatives of the private enterprises involved in the development of H & FC. The EC published its proposal to set up the FCH JU as a legal entity under Article 171 of the Treaty establishing the European Community on 9th October 2007 (European Commission 2007f, 8). The legal text of the regulation and the statutes included the descriptions of the formal governance structure proposed for the FCH JU. This formal governance structure was partly predetermined through the EC's general regulations for the set up of JTIs and partly emerged from the HFP.

The following paragraphs will first illustrate the formal governance structure of the FCH JU in detail in order to illustrate to the reader how the FCH JU was supposed to operate according to its official descriptions. Subsequently, it will be explained how the negotiations of this formal governance structure of the FCH JU in the HFP were mainly driven by private enterprises and by the officials of the EC who were supportive of H & FC. Third, it will be outlined that this important role of the industry relied on the EC's understanding of innovation and its focus on competitiveness. Fourth, the marginal role of public research institutions in the negotiations of the formal governance structure of the FCH JU will be explained as a result of the EC's understanding of innovation and its focus on competitiveness. Finally, the consultation of the EP for the proposal on the set up of the FCH JU and its suggestions for the governance structure of the FCH JU will be illustrated.

*The formal governance structure of the FCH JU*

The official governance structure of the FCH JU is characterized by two executive bodies, the Governing Board and the Executive Director, and three advisory bodies, the Scientific Committee, the States Representatives Group and the Stakeholders' General Assembly as illustrated by the figure beneath:

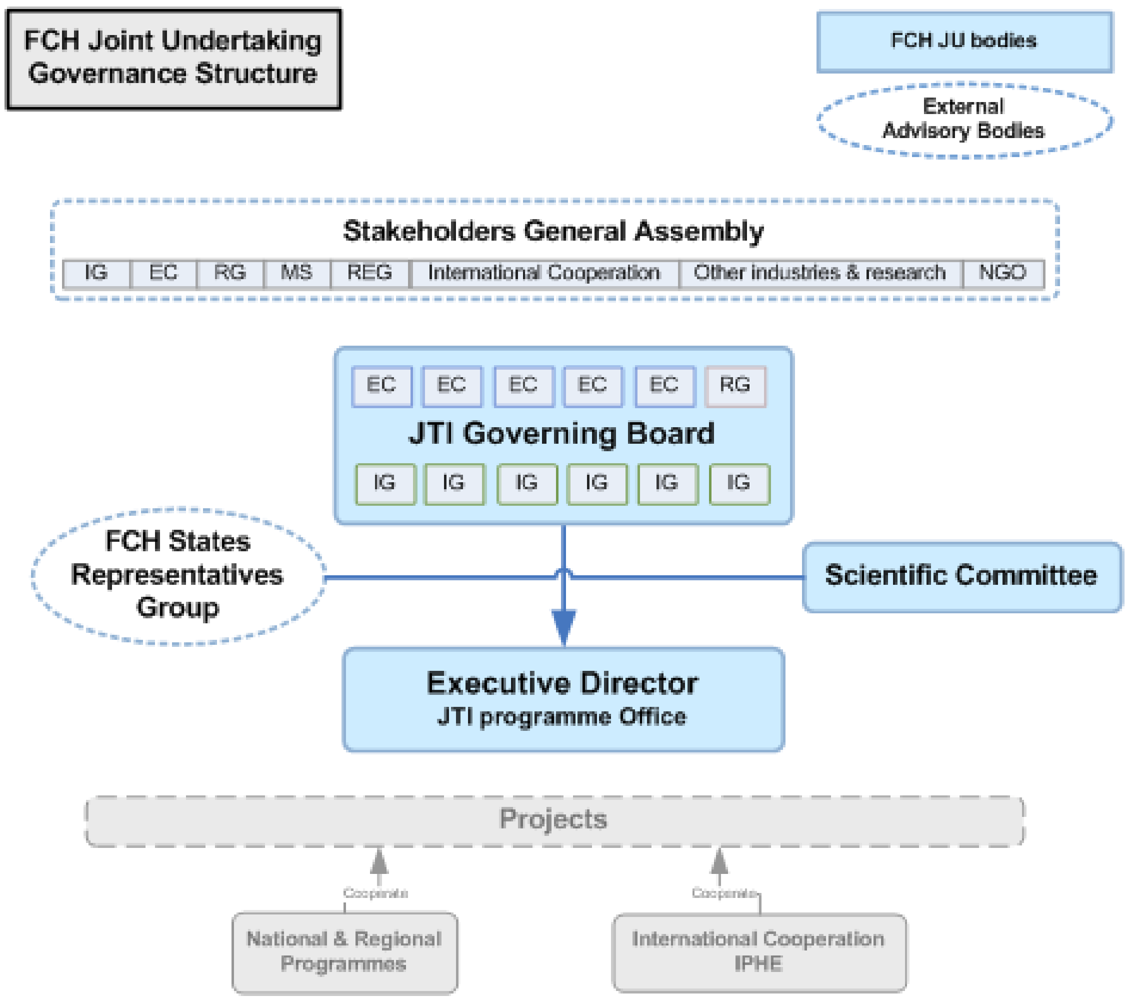



**Figure 14**, The formal governance structure of the FCH JU

Source: (Fuel Cells and Hydrogen Joint Undertaking 2011d)

Abbreviations: IG = Industry Grouping; EC = European Commission; RG = Research Grouping; MS = Member States; REG = Regions; IPHE = International Partnership for Hydrogen and Fuel Cells in the Economy

The Governing Board is to take general decisions on implementation activities, budgets and approval of projects. It consists of six representatives from the NEW Industry Grouping, five representatives from the European Commission and one representative from the N.ERGHY Research Grouping (Fuel Cells and Hydrogen Joint Undertaking 2011e). While the NEW

Industry Grouping is an interest group on H & FC composed of European enterprises (NEW Industry Grouping 2011a), the N.ERGHY Research Grouping represents the interests of European universities and research institutes (N.ERGHY Research Grouping 2011b). The altogether five representatives of the EC comprise three officials from DG R&I, one official from DG ENER, and one from DG MOVE (Fuel Cells and Hydrogen Joint Undertaking 2011e). The Executive Director and his assisting Programme Office are to take care of the daily work in the FCH JU consisting of for instance public relations and the management of funding (Fuel Cells and Hydrogen Joint Undertaking 2011a).

The Scientific Committee is supposed to provide advice on the direction of research and to evaluate the scientific achievements (Fuel Cells and Hydrogen Joint Undertaking 2011f). It is composed of nine representatives from national public administrations, private enterprises and scientific institutes which were selected by the Governing Board (Fuel Cells and Hydrogen Joint Undertaking 2011f). The States Representatives Group is supposed to mediate between the FCH JU and national stakeholders and to provide general advice on the programmes' progress as well as on the coordination with national programmes (Fuel Cells and Hydrogen Joint Undertaking 2011h). It is composed of one representative from each member state and one from each country associated with the seventh FP (Fuel Cells and Hydrogen Joint Undertaking 2011h). The third advisory body, the Stakeholders' General Assembly, is held annually and is open to all parties interested in H & FC (Fuel Cells and Hydrogen Joint Undertaking 2011g). It is not just a platform for the exchange of ideas but also has a formal advisory role to the Governing Board with regard to the future agenda of the FCH JU (Fuel Cells and Hydrogen Joint Undertaking 2011g).

As Figure 14 already indicates, there are also national and regional programmes for the development of H & FC. The largest of the national programmes with regard to financial means was launched in Germany. The National Organization Hydrogen Fuel Cell Technology (hereinafter NOW) was set up in 2008 (National Organisation Hydrogen and Fuel Cell Technology 2011a) with the task to initiate demonstration projects in order to push H & FC toward commercialization (National Organisation Hydrogen and Fuel Cell

Technology 2011b). While it only focused on H & FC at the beginning, it also began to coordinate a programme for the development of battery electric drivetrains in the first years after its launch (National Organisation Hydrogen and Fuel Cell Technology 2011a). The NOW is fully owned by the Federal Government represented by the Federal Ministry of Transport, Building and Urban Development (National Organisation Hydrogen and Fuel Cell Technology 2011a).

The structure of the NOW consists of a management, composed of two persons who take care of the daily work, and an advisory and a supervisory board (National Organisation Hydrogen and Fuel Cell Technology 2011e). The advisory board is composed of eighteen representatives from the national German administration and the industrial and scientific organizations involved (National Organisation Hydrogen and Fuel Cell Technology 2011c). Besides the provision of general advice on the overall programme, the main tasks of the advisory board are the exchange of information, interest mediation among the stakeholders involved, and the consideration of developments at the European and the international level (National Organisation Hydrogen and Fuel Cell Technology 2011c). The supervisory board, whose tasks are not described on the NOW homepage, has five members of which two come from the Federal Ministry of Transport, Building and Urban Development and one each comes from the Federal Ministry of Economics and Technology, the Federal Ministry of Education and Research and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (National Organisation Hydrogen and Fuel Cell Technology 2011d).

European regions and municipalities with an interest in H & FC are organized in HyRaMP, an association that was founded in Brussels on April 14 2008 with the intention to provide a representative body for its members which allows them to speak with one voice to the FCH JU (HyRaMP 2011b). Although not much information on the governance structure of HyRaMP is available, one can say that its board consists of nine representatives from different regions and municipalities (HyRaMP 2011a) and that 30 European regions and municipalities have joined HyRaMP (HyRaMP 2011c). Although neither HyRaMP nor the German NOW hold any formal position in the governance structure of the FCH JU, both contribute their views on the development of H & FC to the discussions on these technologies in the EU.

The paragraphs above have illustrated the formal governance structure of the FCH JU and how the different bodies of the FCH JU were to operate. Subsequently, it will be explained how this formal governance structure was negotiated between the officials of the EC and the representatives of the industry in the following subheading.

*The governance structure as a result of the cooperation of the EC and the industry*

The general regulations for the governance structure of JTIs are deliberately kept flexible to a certain degree so that each JTI can be adjusted to the specific technological challenges, the relationships among the stakeholders involved, and the financing needs (European Commission 2005a, 18). Hence the only general regulation is that each JTI is to have one or more decision-making bodies, a secretariat, and an executive director and that the EC is to be a founding member of each JTI with a veto right against a minimum set of issues which are to be defined individually in each JTI. In addition to the decision-making bodies, the secretariat, and the executive director, a scientific committee may be set up in some cases (European Commission 2007c, 11).

Hence for each JTI proposed, the stakeholders involved must describe the decision-making and management bodies of the legal entity that is to be established and how these bodies are to operate in order to achieve the overall objectives of the JTI (European Commission 2006h, 3). For instance, it has to be clarified whether the Member States representatives are to be founding members of the JTI which means that they would have an executive function and that they would financially contribute to the budget of the JTI or whether they only are to have an advisory role (European Commission 2006h, 3). Furthermore, the rules for the actual implementation of the implementation plan developed, such as, for example, the procedures for the calls for project proposals for funding, are to be defined individually by each JTI (European Commission 2007c, 11).

Consequently, the formal governance structure of the FCH JU partly emerged from the HFP. As already in the consultation process for the Impact Assessment, the private enterprises played a key role in the development of the formal governance structure of the FCH JU. The private enterprises jointly established a not-for-profit association, called the New Energy World Industry Grouping “Fuel cell and Hydrogen for Sustainability” (hereinafter NEW IG), under Belgian Law in Brussels in March 2007 (NEW Industry Grouping 2008, 6). The NEW IG was composed of 45 companies at its launch and served as a platform for their coordination and for the alignment of their interests (NEW Industry Grouping 2008, 7).

The NEW IG was structured into a Governing Board, a secretariat, and four working committees. The Governing Board is composed of six persons in total with one of them being the Chairman of the association, another one being the Treasurer, and the other four representing the four working committees. The members of the Governing Board are elected at the general assembly which is organized at least once a year and which is composed of all member organisations of the NEW IG. The secretariat is in charge of the organization of the general assembly, the meetings of the Governing Board and other activities necessary to ensure the operation of the NEW IG (NEW Industry Grouping 2008, 6, 7).

The four working committees are organized according the different technological areas defined in the field of H & FC: 1) automotive and other transportation, 2) hydrogen production and distribution, 3) stationary power generation and combined heat and power, and 4) early markets. Each working committee is composed of those member organizations that have an interest in the respective technological area. The working committees are supposed to act as a means of coordination between the Governing Board and the member organizations of the NEW IG (NEW Industry Grouping 2008, 6, 7).

The NEW IG and the policy and scientific officers of the EC worked closely together in the development of a governance structure for the FCH JU. All actors involved did, for example, already at the beginning of the negotiations agree upon the need of a more advisory part, the Governing Board, and a more operative part, the Executive Director and the Programme Office. Furthermore, it was clear that the Member States Representatives Group and the General Assembly from the HFP should be continued. Both should function as advisory bodies in the FCH JU. In addition, it was agreed to have a further advisory body in the form of a Scientific Committee. This overall governance structure was inspired by the different actor's experiences in and observations of the development of similar organizations in the USA and in Germany.

*The role of the EC's understanding of innovation and its focus on competitiveness*

The strong involvement and the strong influence of the NEW IG on the governance structure of the FCH JU relied to a large extent on the EC's understanding of the JTI as an instrument that should be led by the industry and that should focus on applied research in order to further develop H & FC towards commercialization. Indeed, the existence of a market failure that prevented H & FC from being commercialized was one of the main reasons for the launch of the JTI in the view of the policy and scientific officers of the EC. Consequently, the FCH JU should be a tool to overcome this market failure which implies that it should focus on applied research led and performed by the industry. This focus on the commercialization of H & FC and the leading role of the industry resulting thereof is well illustrated in the quotation of scientist of the JRC:

> "The people that are best placed to really identify what are the factors that really constitute the market failure are the industries because they have to be able to put their technologies to the market so they are the best placed." (Interviewee 9, 2013)

This view of the JTI for H & FC reflects the EC's broader understanding of innovation and its focus on competitiveness. Innovation was not exclusively but to a large extent associated with the development of new commercial products. Thus all JTIs were launched in areas that, at the time being, were regarded as being of key strategic importance for the EU with the ambition to build up new industrial sectors in these technological areas in the EU such as pharmaceutics, aeronautics, nanoelectronics, embedded computing systems, and fuel cells and hydrogen. The key objective of the EC was to secure the development of these industrial sectors in the EU in order to create new jobs in the future or at least to prevent the relocation of existing industries and jobs to other countries.

The EC's general focus on competitiveness was translated into EU R&I policy as competition with other countries in the development of new technologies. The main argument promoted by the industrial companies and adopted by the officials of the EC was that H & FC will be commercialized anyway so that the main question was not when but rather "in what area of the world the hydrogen vehicle will be developed first" (Interviewee 2, 2012) according to the representative of a car manufacturing company. As the USA and Japan already had launched huge programmes for the promotion of H & FC, the EU was in danger of losing the race in the commercialization of these technologies which could result in the irreversible loss of a potential future industrial sector in the EU and thus in the loss of potential future jobs.

Hence the result of the translation of the EC's general focus on competitiveness into EU R&I policy was a perceived competition with non-European countries in the funding of specific technological areas in order to keep the research and development activities of above all private enterprises in the EU. The underlying ambition was to be the first in the commercialization of H & FC in order to build up a future industrial sector and to secure jobs in the automotive sector in the EU. The fear was that if fuel cells should replace the internal combustion engine as the main powertrain of vehicles in the future, then this would lead to a loss of jobs in the EU. Therefore, an industrial sector manufacturing fuel cells and all the further equipment needed should be built up right from the start.

However, there were also different views between the EC and the industry with regard to the precise role of the Governing Board, the Programme Office, and the Executive Director in the FCH JU. The private enterprises would have favoured an industry-led organization with a Governing Board as the main decision-making body and the Programme Office and the Executive Director taking care of the implementation of the decisions taken. In the view of the industrial actors the FCH JU should have been an organization that decides upon the distribution of its budget completely on its own and that carries out internal audits on the distribution of its budget on its own.

The officials of the EC, however, ensured themselves a veto right on all decisions taken by the Governing Board with regard "to the use of its financial contribution, the methodology for assessing the in-kind contributions, any amendments to these Statutes and the Financial Regulation of the FCH Joint Undertaking and on the issue of coherence of the multi-annual research activity plans with FP 7" (European Commission 2007f, 27). Furthermore, the expenditures of the FCH JU can at any time be checked by different European institutions such as the Court of Auditors and the European Anti-Fraud Office (Council of the European Union 2008, 5, 6).

*The marginal role of public research institutions*

The EC's focus on industry-led research and the strong commitment of the private enterprises were the main drivers in the development of the governance structure of the FCH JU leaving only a marginal role for the public research institutes and universities. The founding members of the FCH JU for instance were to be the EC and the NEW IG. The research community in form of public research institutes and universities was not foreseen to be a founding member at the beginning. However, it should be allowed to become a founding member after the establishment of the FCH JU if it organizes itself in a legal entity in the form of a non-profit association similar to the one of the industry (European Commission 2007f, 25).

Hence the public research community only played a marginal role in the launch of the FCH JU which was mainly driven by the NEW IG and the EC as also the following quotation of a former CEO of a SME illustrates: “A joint undertaking should be launched with two main shareholders who finance it, the industry and the European Commission” (Interviewee 3, 2011). Consequently, also the Governing Board as the main decision-making body of the FCH JU was to be composed of 12 seats with six representatives from the NEW IG and six from the EC (European Commission 2007f, 26).

This marginal role in the negotiations and in the formal governance structure of the FCH JU caused opposition in the research community which attempted to become an official part of the FCH JU. Consequently, the public research community began to organize itself and to claim an official position in the FCH JU in discussions with the EC and the NEW IG. It was agreed that the research community was to get one of the seats from the EC in the Governing Board if it should join the FCH JU as a founding member later on (European Commission 2007f, 26). As a result the N.ERGHY Research Grouping was established as a non-profit association under Belgian law in 2008 (N.ERGHY Research Grouping 2011a).

In fact, the inclusion of the public research community as a founding member of a Joint Undertaking of the EC is rather unusual. The other four Joint Undertakings launched in 2007 and 2008, Eniac for nanoelectronics, Clean Sky for aeronautics, Artemis for embedded computing technologies, and IMI for pharmaceutics, do not include the public research community as a founding member but only industry associations, the EC, and in some cases a Group of Member States. However, that is not to say that public research institutes and universities are not involved at all in these Joint Undertakings. Indeed, the industry associations often include some members from the public research community.

*The consultation of the EP*

According to EU legislation, the set up of a JTI requires the consultation of the EP. Hence the proposal of the EC on the set up of the FCH JU was also discussed in the EP and in particular in the Committee on Industry, Research, and Energy that prepared the draft on the EP's legislative resolution on the proposal (European Parliament 2008). However, the role of the EP in the set up of the FCH JU was rather a marginal one as H & FC in general did not constitute one of the major issues discussed in the EP. Furthermore, most of the amendments of the proposal suggested by the Committee were of a formal nature aiming at issues such as avoiding duplications of paragraphs and articles in the legal text of the proposal and in the Statutes of the FCH JU attached as an annex to the legal text.

Hence the EP did not demand any substantial changes of the proposal of the EC. The few non-formal amendments suggested on the general focus of the FCH JU aimed at strengthening the role of SMEs, public research institutes, and universities. The EP had for instance demanded that the Scientific Committee of the FCH JU is in charge of establishing the scientific priorities for the annual and multi-annual research activity plans and that the contribution of the Research Grouping to the running costs of the FCH JU is reduced from the 1/12 proposed by the EC to 1/20. Apart from these specific amendments suggested, the EP by and large gave its consent to the proposal of the EC.

Finally, the Council of the European Union adopted a slightly revised proposal of the EC on the launch of the FCH JU on 30 May 2008. The formal amendments suggested by the EP were mostly followed. However, the role of SMEs, public research institutes, and universities was not strengthened as the Scientific Committee was only granted an advisory role in the definition of the scientific priorities for the annual and multi-annual research activity plans and not the main responsibility for it as demanded by the EP (Council of the European Union 2008, 14). Furthermore, the financial contribution of the Research Grouping in case it should join the FCH JU later on remained 1/12 as initially proposed by the EC (Council of the European Union 2008, 16).

### 8.2.2 The Multi Annual Implementation Plan

This subchapter explains the development of the Multi Annual Implementation Plan of the FCH JU that outlines the general distribution of the budget available among the different technological areas of H & FC and among the different types of research and development that should be pursued. The negotiations on the distribution of the budget available were driven by the private companies involved in the different technological areas trying to increase the share or the financial resources dedicated to their area. For this purpose, they used specific arguments and expertise in order to emphasize the important of their technological area of interest for the achievement of the climate and energy policy objectives of the EC. Hence the representatives of the private companies approached the officials of the EC individually in order to convince them of the importance of their technological area of interest as the EC had the last say on any decisions about the distribution of the budget.

Together with the other key documents regulating the operation of the FCH JU, the Multi Annual Implementation Plan was developed in the FCHInStruct project. After the officials of the EC and the representatives of the industrial companies involved had agreed upon the formal governance structure outlined in the EC proposal for the launch of the FCH JU, the EC launched the project "Preparatory activities of the Joint Technology Initiative for fuel cells and hydrogen" (hereinafter FCHInStruct) which was led by industrial companies and funded by the EC under the seventh FP (European Commission 2012b). FCHInStruct was officially established on October 1st 2007 and ended by December 2008 (NEW Industry Grouping 2008, 9). The main objective of FCHInStruct was to enable a smooth start of the operation of the FCH JU. For this purpose, the governance process should be specified, a work programme with the strategic objectives for the first two years should be defined, and the rules and regulations governing the evaluation, selection and coordination of project proposals for funding should be developed (Martin 2007, 5).

Hence the key documents regulating the work of the FCH JU and defining the priorities for its first two years of operation such as the Multi Annual Implementation Plan (Fuel Cells and Hydrogen Joint Undertaking 2009), the Annual Implementation Plan for the year 2008 (Fuel Cells and Hydrogen Joint Undertaking 2008a), the Grant Agreement (Fuel Cells and Hydrogen Joint Undertaking 2010b), the Guide for Applicants (Fuel Cells and Hydrogen Joint Undertaking 2008b), and the Rules for Submission (Fuel Cells and Hydrogen Joint Undertaking 2008c)(NEW Industry Grouping 2008, 9) have been developed in the FCHInStruct project before the FCH JU was officially launched. While this subchapter focuses on the explanation of the development of the Multi Annual Implementation Plan, the following subchapters will describe the negotiations of the Annual Implementation Plans and the rules and regulations governing the calls for proposals for funding of the FCH JU.

One of the main objectives of the Multi Annual Implementation Plan was to define the priorities in the research and development of H & FC and to distribute the overall amount of funding available among them. As € 20 million from the overall contribution of € 470 million from the European Community were reserved for the running costs of the FCH JU, the Multi Annual Implementation Plan that was published in May 2009 outlines the how the remaining amount of € 450 million for the period from 2008 – 2013 was to be distributed among five areas of application:

| Application Areas | FCH JU Funding by Action Categories: Break-through research | Research & technological development | Demon-strations | Support actions | TOTAL €m | TOTAL % |
|---|---|---|---|---|---|---|
| Transportation & Refuelling Infrastructure | 20-23 | 20-22 | 94-106 | 10-11 | 144-162 | 32-36% |
| Hydrogen Production & Distribution | 17-20 | 16-19 | 12-15 | 0 | 45-54 | 10-12% |
| Stationary Power Generation & CHP | 23-25 | 95-103 | 35-38 | 1 | 154-167 | 34-37% |
| Early Market | | 11-13 | 42-49 | 1 | 54-63 | 12-14% |
| Cross-cutting Issues | | | | 27-36 | 27-36 | 6-8% |
| TOTAL (€m) | 60-68 | 142-157 | 183-208 | 39-49 | 450 | |
| TOTAL (%) | 13-15% | 31-35% | 41-46% | 9-11% | | 100 % |

**Table 9**, Distribution of the funding available in the FCH JU to the various application areas

Source: (Fuel Cells and Hydrogen Joint Undertaking 2009, 8)

The four main areas of application outlined in the table above have already been defined in the Implementation Plan of the HFP. Also the fifth area of application, cross-cutting issues, was already foreseen in the Implementation Plan as support in the form of, for example, socio-economic studies and the development of educational training activities (European Hydrogen & Fuel Cell Technology Platform 2007, 10).

The distribution of the overall amount of funding available was characterized by the diverging objectives of the different companies present in the different technological areas. Each company attempted to reserve the highest amount possible for its specific area of interest. Of course, at the initial distribution of the overall amount of funding, companies within the same area of application argued in common to increase the overall amount dedicated to their application area. Once this amount was set, however, even companies within the same areas of application argued against each other in order to increase their individual share of the overall funding available for their area of application. Consequently, each company used specific arguments and expertise to achieve its individual objectives.

The final decision on the distribution of the funding lies within the EC due to its veto right on decisions of the Governing Board. As a result of this, each company advocates the importance of its technological area of interest to the officials of the EC. For this purpose, each company uses the discourse on H & FC according to its own interests and underpins its arguments by expert information on H & FC. Proponents of the application area "transportation & refuelling infrastructure" argued for instance that their applications have reached a farther stage in development and are much closer to the market than those in the stationary sector as the following quotation of the former CEO of a SME illustrates:

> "The largest investments and the biggest progress were achieved in the automotive area. Therefore the automotive area was always the focus and should be the focus. There were a lot of discussions on the stationary sector where this has not been the case. There were no assessments in the stationary sector showing what specific technology should be developed and there was a huge gap in the volume of investment. … The automobile industry had invested large amounts in the actual product development while in the stationary sector the development has been slow and in many cases not target-oriented." (Interviewee 3, 2011)

Of course, this critique was met by counterarguments from the stationary sector which aims at developing fuel cells for combined heat and power applications for private households and industrial buildings. The main arguments of the companies in the stationary sector are the potential reduction in $CO_2$ emissions through fuel cells in combined heat and power applications and the high energy efficiency rate of these fuel cells which is to be around 80% compared to only around 50% of the fuel cell applications used in the transport sector.

Hence the general pattern that can be observed is that the different actors of the expertise discourse on H & FC comprised of officials of the EC and representatives of private enterprises and public research institutes spoke with one voice and argued in common only to set H & FC on the European agenda and to launch a JTI for H & FC. In this case their common objective was to increase the political attention dedicated to H & FC, to keep this issue on the agenda, and to receive the highest amount of funding possible for H & FC. However, as soon as it comes to the distribution of the financial resources obtained, the diverging objectives in maximizing the individual benefits prevail over developing H & FC in general.

### 8.2.3 The Annual Implementation Plans

The Multi Annual Implementation Plan not only laid out the amount of funding available for the different areas of application but also the amount available for the annual calls for proposals: 2008: € 28.1 million; 2009: € 70.3 million; 2010: € 90.1 million; 2011: € 106.8 million; 2012: € 73.8 million; 2013: € 80.9 million (Fuel Cells and Hydrogen Joint Undertaking 2009, 21). Based on the Multi Annual Implementation Plan, each year an Annual Implementation Plan is developed. In these Annual Implementation Plans the general objectives and priorities are translated into more concrete topics and the amount of funding available for each year is distributed among the different areas of application.

In the Annual Implementation Plan 2008, that was developed in the FCHInStruct project, the available amount of € 28.1 million was distributed in the following way: 1) transportation & refuelling infrastructure: € 8.9 million, 2) hydrogen production, storage & distribution: € 2.9 million, 3) stationary power generation & CHP: € 12.0 million, 4) early markets € 2.6 million, and 5) cross-cutting issues: € 1.7 million (Fuel Cells and Hydrogen Joint Undertaking 2008a, 9, 10). Furthermore, the Annual Implementation Plan 2008 outlines the topics which are to be pursued in the application areas and which are of crucial importance for the evaluation of project proposals as they determine the themes to which the applicants have to refer and adapt their project proposals in order to receive funding.

For example, for the application area transport and refuelling infrastructure the following four topics have been identified: 1) large-scale demonstration of road vehicles and refuelling Infrastructure, 2) European cluster for large-scale vehicle demonstration – feasibility study, 3) European fuel cell stack cluster – feasibility study, 4) 70MPa compressed $H_2$ onboard storage (Fuel Cells and Hydrogen Joint Undertaking 2008a, 9). In addition, concrete technical targets are defined for each topic. The large-scale demonstration of road vehicles and refuelling infrastructure is, among others, supposed to increase the "refuelling capacity up to 200 kg $H_2$/day for a typical number of 50 vehicles/day, allowing to refill five vehicles within one hour" and to raise the lifetime of vehicles from 2000 hours to at least 3000 hours (Fuel Cells and Hydrogen Joint Undertaking 2008a, 33, 34).

The Annual Implementation Plans have to be formally approved by the Governing Board of the FCH JU. However, while the members of the Governing Board hold the formal authority to decide upon the Annual Implementation Plans, many more actors are involved in the negotiation of their content. Both the N.ERGHY Research Grouping, comprising public research institutes and universities, and the NEW IG, comprising private enterprises, are structured into four main working groups according to the four main areas of application outlined in the Multi Annual Implementation Plan. Each of these working groups discusses internally what topics are to be pursued in the area of application in question and what amount of funding will be required for the projects envisioned. In addition, companies that are not represented in the NEW IG but that are perceived as relevant partners by members organizations of the NEW IG are consulted in this process, too.

However, as already outlined above, many companies and some public research institutes also individually pursue their interests in confidential conversations with the officials of the EC. In these conversations they put forward their specific arguments and expertise in order to illustrate the importance of their specific topic of interest and to outline why it should receive a high amount of the funding available. Each of these actors not only deploys technical arguments on the efficiency rate or the stage in development reached of the specific application of interest but also highlights the importance of this specific technology for achieving more general EU policy objectives such as the reduction of $CO_2$ emissions or the increase of industrial competitiveness and the creation of new markets and jobs.

Hence the use of expertise in the negotiations of the technological priorities and the distribution of the funding available in the Annual Implementation Plans is driven by the different individual objectives of the private companies and the public research institutes participating in the FCH JU. Very specific scientific and technical facts are selected and portrayed in a context that supports the arguments put forward by the actor in question. The following quotation of a representative of a private company exemplifies this issue:

> “It does come down to the relative simplicity of transportation is close to market, the vehicles are arriving, we still do not have a low-cost H2 storage solution which is one of the last barriers to getting the vehicles into the public domain, that is where the money should be going.” (Interviewee 10, 2013)

The success of the individual actors in persuading the officials of the EC of the importance of their specific technological areas of interest depends on the resources in form time and financial means available to them. Large private companies have for instance the resources to employ one or several persons whose main task is to promote their view on H & FC and on other technologies to the officials of the EC. Furthermore, the representatives of large private companies are granted direct access to the high-ranking officials of the EC while this is often denied to the representatives of smaller companies or of public research institutes as already outlined above. Consequently, the representatives of large private enterprises and the high-ranking officials of the EC have more influence upon the distribution of the budget available than any other actors involved in the FCH JU.

In addition, both lobbying activities and general participation in the FCH JU and in the NEW IG depend much on the resources in terms of time and financial means available to the individual actors because neither the work inside of the NEW IG nor a position in the Governing Board of the FCH JU is directly paid for. Hence it does not surprise that the six seats of the industry in the Governing Board are all but one occupied by representatives from large companies such as Air Liquide, Vattenfall, Daimler, Intelligent Energy, and Shell. The remaining sixth seat for the industry is reserved to a SME due to the EC's understanding of innovation in which SME's play a key role in the development of new technologies.

At the same time the EC's understanding of innovation and its focus on commercial products makes it rather difficult for public research institutes and universities to assert their interests in the distribution of the funding available. In fact, the association of public research institutes and universities, the N.ERGHY Research Grouping, plays only a minor role in the development of the Annual Implementation Plans. The focus on innovation as commercial products developed by the industry leaves little room for contributions from public research institutes and universities. One of the main arguments of the industrial companies is that there is only little need for further fundamental research in completely novel technologies but rather the focus should be on further developing and improving the already very well known technologies.

Consequently, a large amount of the funding of the FCH JU is dedicated to projects that rather aim at the demonstration and validation of existing technologies than at the exploration of completely new issues. Participation in these demonstration projects often requires financial resources that public research institutes do not possess. Most research institutes and universities for instance cannot build twenty hydrogen powered fuel cell buses or construct the hydrogen filling stations required to fuel these. Rather, they can participate in these projects by identifying very specific niches for themselves as the following quotation of a scientist of a public research institute illustrates:

> “You could find basic research in the JTI but only if it is linked to a specific product. For example, durability of the membrane of the PEMFC are included and maybe if you want to increase the durability by 20%, maybe, you need to have basic research on the transcuttering, or XRF, very basic research, but its applied to a very specific problem of an existing technology.” (Interviewee 8, 2012)

Of course, at the end of the day, compromises between the different actors with diverging interests have to be reached on the distribution of the amount of funding available. These compromises are facilitated by the officials of the EC, the Executive Director of the FCH JU and also by other industrial actors. These actors function not only as brokers who mediate in case of diverging interests and conflicts but they also try to persuade companies from different areas of application to cooperate in general in order to create synergetic effects and to develop coherent industrial sectors.

In fact, coordinating the different technological sectors and bringing them together is one of the main priorities of the officials of the EC, of the Executive Director and of his Programme Office. One of the main objectives of the launch of the FCH JU was to centralize all EU funding for H & FC in one policy instrument in order to be able to have a coherent and strategic approach for the development of H & FC towards commercialization. Therefore, the EC and the Executive Director attempt to mediate between diverging interests with the ambition of pursuing a balanced approach in the development of a new industrial sector instead of only catering to the particular interests of individual companies. Indeed, while there are still companies that try to lobby the EC on their own, this issue appears to have been reduced over the years after the launch of the FCH JU.

This overall coordination of the development of the FCH JU also affects the negotiation of the priorities of the Annual Implementations Plans. Each year these priorities have to be compared to overall objectives of the FCH JU and its Multi Annual Implementation Plan which outlines very concrete objectives such as, for example, operating 500 buses at 10 EU sites with refuelling stations by 2015 or achieving a cost of € 4000 – 5000 / kW for micro combined heat and power fuel cell applications in the stationary sector by 2015 (Fuel Cells and Hydrogen Joint Undertaking 2009, 7). These targets are discussed in the negotiations of the Annual Implementation Plans as these have to contribute to the achievement of the long-term objectives. Hence both industrial companies and public research institutes who suggest including specific priorities and research topics in the Annual Implementation Plans have to demonstrate the relevance of these priorities with regard to the long-term objectives of the FCH JU.

Finally, a first draft of an Annual Implementation Plan is developed and circulated among the NEW IG, the N.ERGHY Research Grouping, the EC, the Executive Director and his Programme Office, the Scientific Committee, the States Representatives Group, and the JRC. All of these actors can comment on the draft which is revised several times in the scope of this process until at the end a final version is developed and published. Thereafter, the Annual Implementation Plan, outlining the research topics for the call for project proposals of the year in question, is published on the homepage of the FCH JU.

### 8.2.4 Calls for project proposals for funding

This subchapter explains the procedure of the selection of project proposals for funding in the FCH JU. Each year the FCH JU convenes a call for proposals that is to say it invites private and public actors to submit proposals for projects. To be eligible for receiving funding from the FCH JU these project proposals have to address the research priorities outlined in the Annual Implementation Plans. The following paragraphs are to explain the organisation of the calls for proposals and its main issues characterizing it. For this purpose, the formal rules for the evaluation and the selection of project proposals for funding submitted to the FCH JU are outlined first. Subsequently, it is illustrated how the selection of project proposals for funding in the FCH JU proceeds in practice with issues such as European cohesion policy and national H & FC funding programmes playing a role, too.

*The formal rules for the evaluation and the selection of project proposals for funding*

The formal rules for the submission, evaluation, selection, and award procedures for project proposals have been developed during the FCHInStruct project by representatives of the NEW IG and policy and scientific officers of the EC. For the development of these rules, the general regulations for the participation in the FPs were taken into consideration so that each project proposal has to involve at least three different legal entities from different Member States or countries associated with the FP. In addition, there are formal criteria specific to the FCH JU such as that project proposals have to include at least one member organization of either the NEW IG or the N.ERGHY Research Grouping to be considered eligible (Fuel Cells and Hydrogen Joint Undertaking 2008c, 7).

However, apart from a formal eligibility check, the main evaluation of project proposals is to be performed by external, independent experts. These are to be independent in the sense that they are working in a personal capacity and that they in performing the work do not represent any organization. Furthermore, they are to be external to the FCH JU but can be employed at specialized EU agencies (Fuel Cells and Hydrogen Joint Undertaking 2008c, 7).

For each call of proposals, the FCH JU is to draw up a general list of suitable experts according to specific criteria. The two main criteria for the selection of the experts are: 1) A high level of expertise, and 2) An appropriate range of competencies. If these two main criteria are fulfilled, four further criteria should be considered for the selection of the experts: 1) An appropriate balance between academic and industrial expertise and users, 2) A reasonable gender balance, 3) A reasonable distribution of geographical origins, and 4) Regular rotation of experts (Fuel Cells and Hydrogen Joint Undertaking 2008c, 8).

The experts are to evaluate the project proposals with regard to the scientific and technological quality, the quality and efficiency of the proposed management structure and procedures of the implementation, and the potential impact of the project results (Fuel Cells and Hydrogen Joint Undertaking 2008c, 11). Each proposal is to be evaluated by at least three experts who first perform individual assessments before they together have to agree upon a final assessment and write an expert report. If a consensus cannot be reached, the view of the majority is to be outlined in the report including descriptions of the deviant views (Fuel Cells and Hydrogen Joint Undertaking 2008c, 13, 14). Finally, a panel is to be chosen out of the overall pool of the experts that evaluated the proposals in order to compile a final report that lists all the project proposals that have passed the evaluation and those that have failed it (Fuel Cells and Hydrogen Joint Undertaking 2008c, 16). The projects selected for funding have to be approved by the Governing Board of the FCH JU (Fuel Cells and Hydrogen Joint Undertaking 2008c, 18).

The inclusion of external, independent experts in the evaluation of the project proposals gave rise to controversy in the FCHInStruct project. The representatives of the NEW IG would have preferred that the evaluations are carried out internally by the FCH JU that is to say by the Programme Office because in their view the assessment of the proposals should be carried out by those who bear the responsibility for the funding decisions. Furthermore, they criticized that the experts required cannot be external and truly independent because they need to be involved in the development of H & FC to possess the expertise to evaluate the proposals appropriately. The quotation of a former CEO of a SME that has been involved in the FCHInStruct project exemplifies this view:

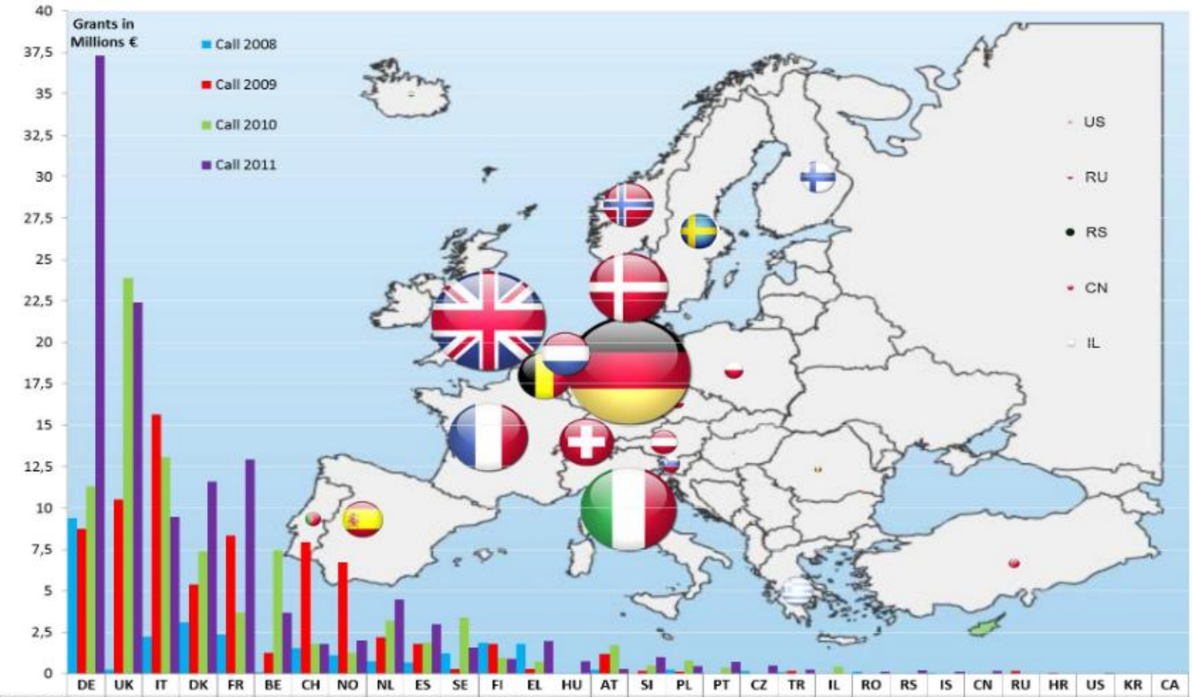
> “The assessment of an issue should be linked to the responsibility for the issue because only then one can assess the economic risk and the overall process. … In addition, another interesting aspect is that these external evaluators, if they are to be truly independent, are not involved as closely in the development of the technology as they should be in order to be able to do their job correctly.” (Interviewee 3, 2011)

The EC, however, insisted on the inclusion of external, independent expert in the evaluation of project proposals. The main argument was that the FCH JU is handling public money and thus appropriate spending has to be ensured under all circumstances. Furthermore, the EC was afraid of fraud and wanted to keep control of the final decision on the funding of projects. Therefore, the officials of the EC were very keen on ensuring their control over the spending of any financial resources in the FCH JU as also the establishment of their veto right on the decisions of the Governing Board indicates.

To raise the knowledge about these rules for submission and to encourage applications for funding, the Programme Office of the FCH JU, the NEW IG, and the N.ERGHY Research Grouping organize public information sessions and brokerage events during each call for proposals. These events are free of charge and can be attended by anyone with an interest in H & FC. The first part of the day is usually being used to explain the procedures for the submission and evaluation of proposals and to illustrate the research priorities and topics for which proposals can be submitted. The second part of the day is organized according to the main areas of application as defined in the Multi Annual Implementation Plan with the aim to facilitate networking and the exchange of ideas among the participants (e.g. Fuel Cells and Hydrogen Joint Undertaking 2014b).

*The actual selection of project proposals for funding*

In addition to the evaluation of the quality of the project proposals submitted, there are several further issues that affect the selection of project proposals funding and also the submission of project proposals in the first place. For example, as in the usual FPs of the EC, cohesion policy plays a certain role in the calls for proposals of the FCH JU. The officials of the EC involved in the FCH JU emphasize the importance of including all Member States in the development of H & FC. The figure below illustrates how the funding available in the first four calls for proposals of the FCH JU was distributed across the applicants from the different Member States:




| | DE | UK | IT | DK | FR | BE | CH | NO | NL | ES | SE | FI | EL | HU | AT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Call 2008 | 9,38 | 0,24 | 2,21 | 3,09 | 2,37 | 0,07 | 1,55 | 1,09 | 0,74 | 0,66 | 1,21 | 1,87 | 1,79 | 0 | 0,22 |
| Call 2009 | 8,73 | 10,5 | 15,6 | 5,36 | 8,32 | 1,23 | 7,95 | 6,71 | 2,18 | 1,81 | 0,27 | 1,79 | 0,26 | 0 | 1,16 |
| Call 2010 | 11,3 | 23,9 | 13,1 | 7,38 | 3,67 | 7,46 | 1,8 | 1,24 | 3,19 | 1,88 | 3,37 | 0,96 | 0,7 | 0 | 1,7 |
| Call 2011 | 37,3 | 22,4 | 9,46 | 11,6 | 12,9 | 3,68 | 1,8 | 2,01 | 4,46 | 2,98 | 1,57 | 0,89 | 1,96 | 0,74 | 0,25 |

| | SI | PL | PT | CZ | TR | IL | RO | RS | IS | CN | RU | HR | US | KR | CA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Call 2008 | 0 | 0,25 | 0 | 0,17 | 0,11 | 0 | 0,11 | 0 | 0,07 | 0 | 0 | 0 | 0 | 0 | 0 |
| Call 2009 | 0,16 | 0,12 | 0 | 0 | 0,15 | 0 | 0 | 0 | 0 | 0 | 0,15 | 0,03 | 0 | 0 | 0 |
| Call 2010 | 0,48 | 0,78 | 0,36 | 0 | 0 | 0,41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Call 2011 | 0,99 | 0,44 | 0,69 | 0,48 | 0,23 | 0 | 0,12 | 0,2 | 0,11 | 0,16 | 0 | 0 | 0,07 | 0 | 0 |

**Figure 15**, Distribution of funding across Member States

Source: (Delplancke, Navas, and Atanasiu 2013, 9)

Apart from Ireland, the amount of funding distributed across the old EU-15 Member States is relatively balanced with the bulk going to organizations in Germany, the UK, Italy, Denmark, and France. However, the figure also reveals that organizations based in the central and eastern European Member States that joined the EU after 2003 almost do not receive any funding at all. Consequently, the FCH JU attempts to encourage the submission of project proposals in these countries by, among others, the organization of public information sessions and brokerage events in these countries (e.g. Fuel Cells and Hydrogen Joint Undertaking 2014a).

The participation in the FCH JU and its calls for proposals is also affected by the national H & FC policies of the Member States. Germany for instance has launched its own public-private partnership for the promotion of H & FC. Different Federal Ministries of Germany contribute altogether € 700 million to the public-private partnership which makes it to the largest programme for the development of H & FC in the EU in terms of financial means. Thus many organizations based in Germany prefer to apply for funding at the national H & FC programme as the rules for application are simpler and as the potential amount of funding that can be received is higher due to the higher overall budget of the German public-private partnership.

Furthermore, in practice the calls for proposals cannot be completely separated from the negotiations of the priorities for each call for proposals outlined in the Annual Implementation Plans as those private enterprises and public research institutes who negotiate the priorities are also those who are supposed to submit project proposals for funding. Hence it is almost inevitable that during the discussions on the research priorities also ideas for project proposals pop up. Different actors might recognize that they have converging interests in one or across two areas of application and start developing an idea for a project proposal. These discussions would be led separately from the general negotiations of the research priorities of the call for proposal in question but still at the same time.

This is not to say, however, that the outcome of the calls for proposals is in any way predetermined during the negotiation of the research priorities and topics for the calls. Rather it means that organizations that more actively participate in the negotiation of the research priorities also have a better sense of the priorities that are discussed and a higher influence on them which in turn increases their chances of developing and submitting a proposal that meets the relevant priorities defined. Hence, in theory, organizations that have higher capacities in terms of time and financial means to actively participate in the FCH JU should also have a higher chance of submitting a successful proposal for funding. In practice, however, even project proposals submitted by organizations well involved in the development of H & FC in the EU in general can be rejected as illustrated by the rejection of proposals of the French industrial gas supplying company Air Liquide, the German consultancy LBST, and the German research institution Forschungszentrum Jülich in the calls for proposals in 2009 (Fuel Cells and Hydrogen Joint Undertaking 2010a, 13).

While the negotiations on the research priorities of a call for proposals might have an impact on the submission of project proposals, the feedback on a call for proposals in terms of the project proposals submitted might in reverse raise discussions on the research priorities defined, too. This can, for instance, be the case if some of the research topics outlined in the call for proposals do not receive any submissions at all. In that case questions, above all from the officials of the EC, arise on why no proposals from the industry or the research community have been submitted although these have been involved in the definition of the research topics. The absence of proposals submitted may, of course, have many reasons with one of them being that different private enterprises and/or public research institutes, due to whatever reasons, could not agree on the specific conditions of carrying out a project together.

### 8.2.5 The decision-making process of the Governing Board

This subchapter explains the decision-making in the Governing Board as a process of gathering and stabilizing expertise on H & FC. The Governing Board is the main decision-making body of the FCH JU and as such it has to approve the Annual Implementation Plans and all project proposals that are to be funded. Its decisions upon the research priorities for each year and upon the quality of the project proposals submitted are based on expertise assessing the quality of the project proposals and the importance of specific technological areas for the overall development of H & FC. During this process of the gathering of expertise many different actors portray their view on H & FC to the members of the Governing Board. Consequently, the final decisions of the Governing Board stabilize the expertise put forward by some actors, while the view on H & FC of other actors is rejected. This process of the gathering and stabilizing of expertise in the decision-making procedure of the Governing Board is described in more detail in the following paragraphs.

The Governing Board is composed of six representatives from the NEW IG, five from the EC, and one from the N.ERGHY Research Grouping. The Governing Board members come from the higher hierarchical levels of the EC. In 2012 for instance Rudolf Strohmeier, the Deputy-Director General of DG R&I, Raffaele Liberali, the Director of the Directorate K Energy of DG R&I, Theodius Lennon, the Director of the Directorate R Resources of DG R&I, Tudor Constantinescu, the Principal Advisor to the Director General of DG ENER, and Jean-Eric Paquet, the Director of the Directorate European Mobility Network of DG MOVE represented the EC in the Governing Board of the FCH JU. Hence these five persons held the formal voting rights for the EC in the decisions of the Governing Board.

However, many more officials from the lower hierarchical levels of the EC are involved in the preparation of the decisions of the Governing Board. In fact, each meeting of the Governing Board is preceded by internal meetings inside of the EC in which the policy and scientific officers from the Directorates that financially contribute to the FCH JU brief the Governing Board members of the EC on the decisions to be taken at the meeting. While the Governing Board members hold the formal voting rights in the FCH JU, the policy and scientific officers are much more involved in the day-to-day operations of the FCH JU. They have close contact to the Executive Director and the Programme Office and, at least in the first years of the FCH JU, assisted them in the administrative work related to the organization and evaluation of the calls for proposals.

Consequently, it is the policy and scientific officers who gather the expertise required for the decisions of the Governing Board members of the EC. The policy and scientific officers suggest for instance based on their insights in the evaluation procedures whether the Governing Board members should approve or reject the project proposals for funding submitted in a call for proposals. These suggestions are critically analyzed by the Governing

Board members of the EC and have to be justified in the briefings before the actual Governing Board meetings as the following quotation of an official of the EC illustrates:

> ”There was a call for proposals, projects, the evaluation went on, we have a report of the evaluation, there is a proposal for projects to be funded etc., and the Commission is asked, the Governing Board is asked to endorse the proposal of the FCH JU. So we here will analyze the reports, see if everything has been done okay, if the projects seem okay and if we do not see any problem, then we will recommend to our hierarchy to vote okay. We brief the Commission members of the Governing Board before they go to the meetings and we propose them things, but if they do not agree, believe me, they will tell us and then we discuss and if we think we have proposed a good decision, then we explain why and eventually they say no or yes.” (Interviewee 11, 2013)

Hence the procedure preceding the decisions taken by the Governing Board members of the EC resembles the general decision-making procedure in the EC. While the formal decisions are taken by the Commissioners of the EC, the practical and technical expertise upon which the decisions are taken is gathered by the lower levels in the hierarchy of the EC. During the meetings inside of the EC the basis of the expertise is double-checked by the critical questions of the Governing Board members in order to ensure validity of the information put forward.

Similar hierarchical structures have been built up in the NEW IG and the N.ERGHY Research Grouping. While the six Governing Board members of the NEW IG also chair the six committees on the different areas of application and one of them acts as the treasurer of the NEW IG, each of them has at least one vice-chair that takes care of the more detailed work in the committee in question. Also the N.ERGHY Research Grouping is organized into different working groups corresponding to the areas of application defined in the FCH JU. Each of the working groups has a different chair that coordinates the more detailed internal work, while the general chair of the N.ERGHY Research Grouping, Paul Lucchese from the

Commissariat à l'énergie atomique in France, represents the association's interests in the Governing Board of the FCH JU.

While the idea behind the different committees in the NEW IG is that the different companies involved reach a consensus so that they speak with one voice in the discussions with the EC representatives, this does not always work out in practice. Rather, companies that do not see their technological area of interest well represented in the consensus reached in the committees of the NEW IG attempt to lobby the EC representatives directly to assert their interests. For this purpose, there are personal, confidential meetings between individual actors of the NEW IG and the EC representatives scheduled around the actual meetings of the Governing Board. In these confidential meetings individual actors attempt to persuade the EC representatives of the importance of the specific technological areas of H & FC that are of interest to them.

Hence, to a certain extent, these individual, confidential meetings undermine the general consensus building process in the NEW IG and in the Governing Board and also the overall governance of the FCH JU. In fact, the organizational structure of both the NEW IG and the FCH JU was built in order to facilitate consensus building among different actors in different technological communities so that a coherent approach for the development of H & FC towards an emission-free energy and transport system can be established. In contrast, pursuing particular individual interests might lead to the funding of very specific technological areas that might not play a key role in the emission-free energy and transport system envisioned but rather only serve the particular interests of the actor in question.

Thus the decision-making process of the Governing Board is not only a question about the gathering and stabilization of expertise but also about the strategic use of specific expertise on H & FC. The main point is to reach a consensus on what technologies will be needed to contribute to the achievement of the overall EU energy, innovation, research, and transport policy objectives. For this purpose, different actors attempt to highlight the relevance of their specific technologies or technological areas of interest for the achievement of these objectives. In order to counterbalance the weight of particular interests, the policy and scientific officers of the EC attempt to have a wide range of different sources of expertise and keep close contacts to the Executive Director and his Programme Office and consult further experts in the field of H & FC such as the JRC.

### 8.2.6 The States Representatives Group, the Scientific Committee, and national and regional H & FC programmes

This subchapter explains the roles of the States Representatives Group, the Scientific Committee, and national and regional H & FC programmes in the governance of the FCH JU. Both the States Representatives Group and the Scientific Committee only play minor, advisory roles in the governance of the FCH JU. While many members of the States Representatives Group lack the resources to actively participate in the discussions of the Group, the members of the Scientific Committee are only marginally involved in the development of the research priorities outlined in the Annual Implementation Plans and mostly just confirm the draft versions sent to them. Consequently, both bodies only play minor roles in the overall governance of the FCH JU.

In contrast, the national and regional H & FC programmes, although not being officially represented through a body in the FCH JU, have a considerable impact on its governance. Above all the German public-private partnership for the development of H & FC had a strong impact on the governance of the FCH JU due to its higher budget. In addition, many of the large private companies involved in the FCH JU have carried out their H & FC activities in Germany in many years which has brought about a cohesive network of actors with close ties to each other. These actors cooperated closely at the national level where they exchanged their views on the FCH JU and discussed whether they should pursue a common strategy at the European level. Their resources in the form of time and financial means enabled them to have a strong imprint on the governance of the FCH JU and to get their voices heard.

The following paragraphs will describe these issues in more detail. First, the low participation in the States Representatives Group is outlined. Thereafter, the national and regional H & FC programmes and their impact on the governance of the FCH JU is illustrated. Finally, the minor role of the Scientific Committee in setting the research priorities of the FCH JU is described.

*The low participation in the States Representatives Group*

The States Representatives Group is officially composed of 31 representatives; one from each participating country of the then 27 Member States of the EU and from the four countries associated with the seventh FP. These representatives were chosen by their national research ministries or research agencies which were contacted by the policy and scientific officers of the EC with the appeal to appoint a person to the States Representatives Group. Many of the representatives have already been part of the Mirror Group which was the Member States representatives' group in the Hydrogen and Fuel Cell Technology Platform.

The States Representatives Group meets twice a year and is supposed to align the research and development priorities of the FCH JU with the national H & FC programmes. For this purpose, the Member States representatives are, among others, invited to comment on the drafts of the Annual Implementation Plans. The meetings of the States Representatives Group are also attended by the Executive Director and the Programme Office of the FCH JU and by EC representatives from different hierarchical levels of DG R&I. However, only the representatives of countries with national H & FC programmes and projects such as, for instance, Denmark, Germany, France, Norway, and the UK, actively participate in the meetings while many of the other representatives do not contribute to the discussions.

This low level of participation is partly due to the fact that many of the Member States Representatives are employed at national research agencies or institutes with only weak ties to their national governments. Hence they do not hold any formal decision-making authority at the national level which could increase their bargaining power at the European level. Furthermore, in many Member States there are no or only very few H & FC projects so that the representatives from these countries use their involvement in the FCH JU to observe what is happening at the European level and to evaluate what could be done to promote H & FC in their own countries. Hence the actual adjustment of the research and development priorities of the FCH JU and the national H & FC programmes that the States Representatives Group is supposed to provide cannot take place in many countries as these do not have any national H & FC activities.

However, also in Member States with significant national H & FC programmes the principle of subsidiarity is not systematically taken care of. Although the representatives of the Member States that do have national H & FC programmes compare their national R&I objectives with those outlined in the Annual Implementation Plans, they lack the resources to systematically ensure that similar research projects are not funded at both the European and the national level. Furthermore, neither the national H & FC organizations nor the FCH JU made the effort to systematically clarify which technological areas of H & FC should be developed at the European and which ones at the national level.

In fact, it has been discussed how the development of H & FC could be coordinated on the regional, national, and European level in a complementary way. Some Member States representatives have suggested that the FCH JU takes care of research and development that is of European relevance such as, for example, the development of an EU-wide hydrogen infrastructure or the development of quality standards and methods to ensure them. In contrast, the further development of, for example, specific components of a fuel cell could also be organized at the national levels. However, a more systematic approach for the coordination of research and development between the European and the national level has not been implemented so far.

Another issue that is being discussed in the States Representatives Group between the Member States representatives and the EC representatives is in how far European cohesion policy should play a role in the FCH JU. The representatives of the Member States with strong national H & FC programmes for instance strategically deploy the European discourse on competitiveness and argue that the EU needs world-class research if it wants to catch up to the US and Japan and therefore rather should support the advanced national H & FC programmes than to balance the stage in development in the diverse European countries. Hence their main argument is that if the EU wants to compete with the USA and Japan and secure a leading position in global research and innovation, it should rather focus on further supporting Member States with a strong performance in research and innovation than on slowly improving the weak performance of other Member States.

This line of argumentation is, of course, not supported by Member States with minor or without any national H & FC programmes. Rather they argue that the EU R&I programmes such as the FCH JU should include all Member States as this is what the EU is for. Otherwise, Member States who are not included in the development might wonder why they are part of the EU in the first place. In fact, the EC as well as the Executive Director and his Programme Office are trying to encourage the participation of organizations from Member States with no national H & FC programmes in the FCH JU. However, so far these efforts have been met with limited success as already outlined above.

*The role of national and regional H & FC programmes*

In contrast to the many Member States with minor or without any national H & FC programmes, there is significant cross-border cooperation between various private and public organizations from the five Member States with the highest share of the funding of the FCH JU which are Germany, the UK, Italy, Denmark, and France. These actors organized in the NEW IG and the N.ERGHY Research Grouping not only carry out H & FC research and demonstration projects together but also develop common strategies of how to lobby their national policy-makers to increase the spending on H & FC. Indeed, national H & FC programmes such as UK H2 Mobility in the UK or AFHYPAC in France and have been launched in recent years. In addition, national H & FC programmes have already been in existence before the launch of the FCH JU in Denmark, Norway, and Sweden.

The biggest national programme, however, was launched in Germany in parallel to the FCH JU. The Federal Government of Germany together with industrial companies and public research institutes launched a national public-private partnership by setting up the National Organization Hydrogen Fuel Cell Technology (hereinafter NOW) in 2008 (National Organisation Hydrogen and Fuel Cell Technology 2012). The task of the NOW is to initiate demonstration projects in order to push H & FC toward commercialization (National Organisation Hydrogen and Fuel Cell Technology 2012).

For two reasons, the German NOW constitutes an important factor in the governance of the FCH JU. First, the budget of the NOW is almost twice as high as that of the FCH JU. While the EC contributes € 470 million to the FCH JU for the period from 2008-2017, the German Federal Ministry of Transport, Building and Urban Development and the Federal Ministry of Economics and Technology contribute € 700 million to the National Innovation Programme Hydrogen and Fuel Cell Technologies that is to be implemented by the NOW (National Organisation Hydrogen and Fuel Cell Technology 2012). Consequently, German companies prefer to apply for project funding at the NOW as the application procedure is simpler and the amount of funding available is higher.

Second, there is a cohesive German H & FC community composed of policy-makers, scientists and representatives from the industry and the national platform. For example, besides several other German actors involved in the FCH JU, two of the six industry representatives in the Governing Board in 2012 came from Germany, and one scientist from the University of Ulm in Germany was in the Scientific Committee. These persons are also represented in the formal governance structure of the NOW and they have already worked together in several previous German organizations for the promotion of H & FC.

These actors belong to a much broader German H & FC community that has grown together over several years during which trust and close ties have been established. This German H & FC community discusses European developments, exchanges views and develops a common stance before it goes back to the European level. During the development of the Annual Implementation Plans that set the objectives and the direction of research, German scientists and representatives from the national platform and private companies meet and develop a common view that they present to the FCH JU later on.

Against this background it is not surprising that the most committed European region in the development of H & FC is North Rhine-Westphalia in Germany. Together with other European regions interested in the development of H & FC, North Rhine-Westphalia is a member of HyRaMP; the hydrogen and fuel cell association of the European regions. The members regions of HyRaMP are actively involved in the H & FC research and demonstration projects that are performed in their respective area. However, the role of HyRaMP in the overall governance of the FCH JU is rather a marginal one.

*The minor role of the Scientific Committee*

Similar to the States Representatives Group, also the Scientific Committee only plays a minor, advisory role in the overall governance of the FCH JU. In 2012 the Scientific Committee was composed of seven persons. The policy and scientific officers of the EC asked the States Representatives Group to suggest eligible candidates for the Scientific Committee. The candidates were supposed to have relevant expertise in the field of H & FC acquired either in academia, industry or public administration. Hence it is not surprising that the members of the Scientific Committee come from countries with national H & FC programmes such as the UK, Austria, Germany, Norway, the Netherlands, France and Italy.

The Scientific Committee meets only two to three times per year and can suggest corrections on the research and development priorities outlined in the drafts of the Annual

Implementation Plans. The main task of the Scientific Committee is to provide advice on whether these research and development priorities correspond to the global development of H & FC and the scientific and technological state of the art. However, as many of the private and public organizations of the NEW IG and the N.ERGHY Research Grouping are actively involved in the global development of H & FC and participate in H & FC projects in non-EU countries, too, the research priorities outlined in the Annual Implementation Plans are mostly in line with the state of the art in H & FC development. Therefore, the members of the Scientific Committee usually agree to the research and development priorities proposed and only suggest marginal revisions as the following quotation of a Member of the Scientific Committee exemplifies:

> "As the Scientific Committee is only to meet one or two times a year, it gets the role that it now has that is to say to marginally modify already taken decision and predefined programmes. ... Of course one could try to change something but it is not the case that these persons just write down anything but rather these priorities have naturally developed and they are similar in Germany and on the global scale and therefore there are no bigger surprises when of these programmes is being strategically developed. One could say that the objectives outlined for the stationary area of application are not sufficiently specified. This would be an example of a marginal revision where we would say that the objective of longer lifetimes has to be quantified." (Interviewee 1, 2011)

### 8.2.7 Problems encountered

This subchapter illustrates the two main problems that arose in the implementation of the FCH JU as perceived by the actors involved in it. These were the actual establishment of the FCH JU as an autonomous organization with its own staff that took more than two years and the funding rates for the projects accepted for funding that were considered as being too low.

It is important to emphasize, however, that this is the perception of the main actors involved in the implementation of the FCH JU. Consequently, other actors who were not involved in the implementation of the FCH JU might have come to a different assessment and would have stated other issues as the main problems in the implementation of the FCH JU. In fact, the interim evaluation of the FCH JU that was performed by external, independent experts in 2011 will be explained in the next subchapter.

However, the following paragraphs will first describe that the actual establishment of the FCH JU as an autonomous organization with its own staff took more than two years. Thereafter, it will be highlighted that the funding rates for the projects accepted for funding were considerably lower than in the usual funding schemes of the FP due to the legal regulations of the FCH JU. The two issues, the autonomy of the FCH JU and the low funding rates were considered as the two main problems by the officials of the EC and the representatives of the private enterprises and the public research institutes involved in the implementation of the FCH JU.

*Autonomy and the selection of the staff*

While the FCH JU was officially launched in 2008, the recruitment of the Executive Director and the staff of the Programme Office was not completed until the end of 2010. Bearing in mind that the FCH JU was set up for the period of 2008-2017 this means that the FCH JU had to operate more than 2 years or more than a quarter of its overall lifetime without its own employees. Instead, policy and scientific officers of the EC had to carry out the operation of the FCH JU in the first two years until the recruitment was completed. Hence the governance structure of the FCH JU could not work as it was supposed to in the first three years of operation as also the following quotation of a scientist of a public research institute illustrates:

> "So that means that at the beginning, two or three years ago, there were only three or four people to manage the call and the Commission was helping, people from the Commission, and that means that a lot of work was not done. For example, communication, a lot of things were not done because there was no one to do the job. So they focused, of course, on the calls and the calls were very late in 2008, 2009 and 2010." (Interviewee 8, 2012)

In a report on the state of the implementation of all JTIs published in January 2010 it is stated that three of the five JTIs launched have become autonomous and that the remaining two, among which the FCH JU, are expected to become autonomous by March 2010 (JTI Sherpas' Group 2010, 5). The autonomy of the three JTIs is celebrated as a major achievement in itself "as it has taken significant efforts on all sides to reach this point" (JTI Sherpas' Group 2010: 2, 8). In the first interim evaluation of the FCH JU that was conducted in spring 2011 it is stated that the FCH JU became an autonomous body only a few months before the evaluation was undertaken (European Commission 2011d, 18). Hence from the official set up of the FCH JU in May 2008 it took more than two years to establish its autonomy.

Autonomy in the context of the FCH JU means that the FCH JU has its own staff and its own equipment such as IT systems for the accomplishment of the daily work and does not rely on the facilities of the EC and the assistance of the EC's policy and scientific officers. Therefore, the main reason why it took so long to establish the FCH JU as an organization that is able to stand on its own feet is the recruitment of the Executive Director and the staff of the Programme Office. The FCH JU was over a long period of time not carried by its own employees but rather by an interim team of officials of the EC (Vannson 2009, 12) and by an interim Executive Director who also came from the EC (European Agenda 2012).

In the first interim evaluation of the FCH JU the official status of the FCH JU as a Community Body is often named as the punching bag for the delay in recruitment of the staff of the FCH JU. Due to its status as a Community Body the FCH JU has to apply the same formal rules for the selection of staff as the EC for its employees. The evaluation report criticizes that these rules are “designed for much more complex and less directly managed operations” and thus are not appropriate to public-private partnerships of the scale of the FCH JU (European Commission 2011d, 18). Due to these issues, the evaluation report acknowledges that the FCH JU is not fully independent as the notion of “autonomous does not extend to staff management and financial processes which must adopt EC processes” (European Commission 2011d, 18).

The large delay of more than two years in the recruitment of the Executive Director and the staff for the Programme Office did, however, not only rely on formal issues. Rather, the Executive Director and the Programme Office play an important role in the administration and assessment of project proposals and thus different actors in the NEW IG and in the EC attempted to place their desired candidates into these positions. While the representatives of the NEW IG argued that the staff of the Programme Office should come from industrial companies so that it has the technical expertise required to administer and to evaluate the H & FC projects funded, the representatives of the EC feared that persons who have worked in specific industrial companies and in specific technological areas would not have the neutrality required to manage the FCH JU as a whole but rather would end up in a conflict of interest. As a matter of fact, the Executive Director selected, Bert de Colvenaer, comes from the industry, while most of the staff of the Programme Office were either directly employed by the EC or worked at public research institutes before they came to the FCH JU.

*The amendment of the funding rates*

A further issue that was discussed controversially in the Governing Board were the regulations on the funding rates of the FCH JU. Article 2, 12, and 15 of the legal Statutes of the FCH JU stated that the financial contribution of the industrial actors participating in the research and development projects funded by the FCH JU should at least match the financial contribution of the European Community. Furthermore, the legal entities participating in the H & FC projects funded by the FCH JU have to contribute financially to the general operational costs of the FCH JU through in-kind contributions that in sum at least match the financial contribution of the EC. That is to say that the operational costs of the FCH JU, consisting above all of the administrative work of the Executive Director and the Programme Office in the management of the calls for project proposals, had to be covered equally by the EC on the one side and the legal entities participating in the projects funded on the other side.

Altogether, these regulations led to considerably lower funding rates in the projects funded by the FCH JU compared to the usual funding rates in the FPs. In particular the participation of public research organizations in the research and development projects led to a reduction of the funding rates as the financial contribution of the FCH JU only had to match the contributions of the industrial actors involved in the project in question, while the financial contribution of the public research institutions was not taken into account. Hence the overall amount of funding available for a specific research project did not increase with the involvement of public research institutions in the project but rather had to be distributed among more actors which led to lower funding rates for each actor participating in the project in question. In fact, in the projects funded under the call for proposals in 2010 the funding rate for industrial actors was 36% compared to the usual 50% in the FPs. Other participants such as public research organizations and SMEs received funding rates of 54% compared to 75% in the FPs (Fuel Cells and Hydrogen Joint Undertaking 2011b, 14).

These comparably low funding rates caused controversial discussions in the Governing Board and various suggestions were made for an amendment of the Statutes of the FCH JU. Above all the public research organization and universities argued for an amendment that would lead to higher funding rates. Finally, it was agreed in the Governing Board to develop a proposal that would suggest including the financial contribution of public research organizations into the amount that the financial contribution of the European Community has to match. The amendment of the Statutes of the FCH JU was approved by the Council of the EU on 14 November 2011 (Council of the European Union 2011).

However, even after the implementation of the amendment, the improvement in the funding rates turned out to be lower than expected. The research and development projects that were selected for funding in the calls for proposals in 2011 and 2012 had actual funding rates of 40% for industrial companies and 60% for SMEs and public research organizations. Hence the funding rates were still lower than in the collaborative research projects of the FP in which industrial actors could get 50% and public research institutions 75%.

## 8.3 The first interim evaluation of the Fuel Cell & Hydrogen Joint Undertaking

The first interim evaluation of the FCH JU was part of the general evaluations of the altogether five JTIs of the EC which took place in parallel in 2010 and 2011. This affected the interim evaluation of the FCH JU that was carried out by an expert panel in two main ways. First, the officials of the EC ensured that the evaluations of the different JTIs produced a set of comparable, general results that could be used in the internal communications of a public administration. For this purpose, the officials of the EC developed a general set of questions on the effectiveness, efficiency, and quality that should be answered by the different expert panels for each individual JTI. The general results received from the different expert panels could be used by the officials of the EC to illustrate the assessment of the different JTIs to other EC officials who were not involved in the set-up and the operation of these.

Second, the officials of the EC ensured that the different expert panels developed recommendations for the improvement of the operation of the different JTIs that the EC could use in the further policy process. The expert panel evaluating the FCH JU was for instance asked to make a recommendation on whether the FCH JU should be continued in the upcoming FP 8 or not. This recommendation could be used by the officials of the EC in the negotiations on FP 8 which were to start soon after the evaluations of the different JTIs had been completed. Hence the evaluations of the different JTIs have been influenced by the general bureaucratic logics of the EC as a public administration which not only needed general results that allowed a comparison of the operation of the different JTIs but also results which could be used in the further course of the policy process.

Hence the evaluation of the FCH JU was conducted by the expert panel in cooperation with the officials of the EC. However, in addition to providing practical advice and ensuring that the evaluation satisfies the internal bureaucratic needs of the EC, the officials of the EC also attempted to influence the results of the evaluation to a certain extent by promoting their own views on the operation of the FCH JU to the members of the expert panel. Above all the officials from the higher hierarchical levels of the EC had their own views on the operation of the FCH JU and whether it should be continued and illustrated these views to the expert panels. In so doing the officials of the EC exerted a degree of pressure on the member of the expert panel to adopt their views on the FCH JU and its potential continuation.

To explain these developments in more detail and to fully account for the conduct of the first interim evaluation of the FCH JU, this subchapter is structured into five parts. First, the main outcomes of the evaluation as outlined in the evaluation report will be illustrated. Second, the selection of the experts will be described. Third, the data collection for the evaluation will be illustrated. Fourth, the compilation of the final evaluation report will be highlighted. Fifth, the consequences of the recommendations of the evaluation will be described focusing on the revision of the Multi Annual Implementation Plan. In all of these five parts the specific roles of the members of the expert panel and the officials of the EC in the conduct of the evaluation will be illustrated.

### 8.3.1 The main outcomes of the first interim evaluation

According to the Council regulation on the launch of the FCH JU, an evaluation had to be conducted at the mid-term of the operation of the FCH JU which was to run from 2008-2017. Consequently, an interim evaluation of the FCH JU was conducted in 2011; only a few months after the staff selection for the Programme Office had been completed. The evaluation was carried out by six experts who were assisted by a secretary team composed of policy and scientific officers of the EC. Most of these belonged to DG R&I and were in charge of dealing with the FCH JU. The overall evaluation process took around six months from the first meeting in December 2010 to the publication of the final version of the First Interim Evaluation report in May 2011. After a general introduction and the explanation of the background of the FCH JU in the first two sections, the actual outcomes of the evaluation are outlined in the third, fourth, and fifth section of the First Interim Evaluation report.

The third section is structured according to the three main criteria by which the performance of the FCH JU was analyzed: 1) effectiveness, 2) efficiency, and 3) quality. Concerning the effectiveness of the FCH JU, the expert panel has focused on describing achievements and opportunities for improvement under seven main points such as programme management, industrial participation, regulations, codes, and standards, cohesion with Member States' activities, finance, communications, and international cooperation (European Commission 2011d, 18–24). The description of the efficiency of the FCH JU highlighted the two issues of processes and portfolio management, while the quality of the FCH JU was primarily assessed by elaborating whether the FCH JU will be able to achieve its overall objective of the commercialization of H & FC in a coordinated manner (European Commission 2011d, 18–24).

The fourth section constitutes a SWOT analysis and thus places all the strengths, weaknesses, opportunities, and threats identified in the evaluation of the FCH JU under the corresponding heading (European Commission 2011d, 18–24). Finally, the fifth section outlines the conclusions drawn and the recommendations made by the expert panel. In general the experts recommend that the FCH JU should be continued and further supported in its work so that it can achieve the initial objectives defined at its launch. Apart from this general advice, the experts have developed five more concrete recommendations with each of them including several very specific subitems (European Commission 2011d, 18–24).

First, the experts recommend to reinforce the portfolio management of the FCH JU which means, among others, to revise the Multi Annual Implementation Plan that sets the research and development priorities and distributes the available funding among the different areas of application. Second, it is recommended that the FCH JU should ensure a high agility of its operations and a high adaptability to changing competitive forces. This means, among others, that complementary relationships with the battery technology should be explored and that a strategic plan for the development of stationary applications should be developed. Third, it is recommended that the FCH JU improves its visibility and develops an effective communication strategy (European Commission 2011d, 18–24).

The fourth recommendation was to improve the collaboration and the alignment with the Member States' parallel activities in H & FC. For this purpose, the members of the States Representatives Group should be better connected to their national policy-makers, they should be more actively involved in the FCH JU, and joint funding schemes between the FCH JU and the Member States should be explored. Finally, the fifth recommendation was to ensure a high efficiency of the operations of the FCH JU. This recommendation referred, among others, to the legal status of the FCH JU which should be streamlined and to the resources of the Programme Office to actually manage and monitor research projects instead of just administering them (European Commission 2011d, 18–24).

### 8.3.2 The selection of the experts

The six experts who compiled the report are: 1) Elisabet Fjermestad Hagen who before her retirement in 2008 represented Norsk Hydro ASA in various European H & FC institutions, 2) John Loughhead who is the Executive Director of the UK Energy Research Centre and who had been involved in various European H & FC institutions, 3) Jens Rostrup-Nielsen who is a founding member of the Scientific Council of the ERC and who had represented the Danish company Haldor Topsøe A/S in various European H & FC institutions, 4) Maria-Rosaria Di Nucci who is an associate senior research fellow at the Environmental Policy Research Centre of the Free University of Berlin, 5) Ana Sofia Caires Sousa Branco who is a

Technological Physics Engineer, and 6) Manfred Horvat who is a Honorary Professor for European and International Research and Technology Cooperation at the Vienna University of Technology (European Commission 2011d, 18–24).

These experts have been selected and contacted by the policy and scientific officers of the EC. The EC has general lists of persons who can be contacted in order to function as independent experts in evaluations. In the selection of experts for specific evaluations, the EC applies it general criteria which is to say that experts should have a high level of expertise and an appropriate range of competencies. Furthermore, there should be an appropriate balance between academic and industrial expertise and users, a reasonable gender balance, a reasonable distribution of geographical origins, and a regular rotation of experts (Fuel Cells and Hydrogen Joint Undertaking 2008c, 8).

The above named experts match these criteria pretty well as all of them have held or are holding high positions in industrial companies, public research organizations or public administration. Three of the experts have firsthand experiences in EU H & FC projects, while the other three have been evaluators in several EU R&I projects. Hence all of the experts selected have already had personal contact to either the members of the EC's secretary team or other policy and scientific officers of the EC. One of the experts, Manfred Horvat, was also a member of the expert panels that evaluated the JTI on aeronautics and the JTI on pharmaceutics. All three evaluations took place at the same time and Mr. Horvat was to compare the evaluations in relation to each other. Furthermore, women and men were equally represented by three members each in the expert panel and all of the six experts had different citizenships (Norway, UK, Denmark, Italy, Portugal, and Austria).

### 8.3.3 Data collection

At the first meeting of the expert panel which took place in December 2010 the officials of the EC presented the terms of reference for the evaluation of the FCH JU that is to say they explained how the panel was supposed to work and what the objectives of the evaluation are. A chair person and a rapporteur were selected among the experts. While the role of the chair person was to coordinate the work and the discussions of the expert panel, the rapporteur was the one responsible for compiling the drafts of the evaluation report.

At further meetings the representatives of the EC presented lists of questions that the expert panel was to answer through interviewing relevant stakeholders in the FCH JU. Most of the questions were summed up under the three criteria of the effectiveness, the efficiency, and the quality of the work of the FCH JU. These criteria came from the evaluations of other JTIs that had been almost completed before the evaluation of the FCH JU began. Furthermore, the officials of the EC briefed the expert panel on how the FCH JU has been established and on its main activities since its launch. Also the governance structure of the FCH JU with all the different bodies such as the Governing Board and the States Representatives Group and all the different institutions involved such as the NEW IG and the N.ERGHY Research Grouping was explained to the experts.

The experts examined the list of questions provided to them by the EC and decided to amend some of the provided ones so that they seemed more relevant to the purposes of the evaluation and to add a few questions mainly with regard to the industry's perspectives on the market. Furthermore, the experts discussed and decided on their own what actors they want to interview for the evaluation. According to the presentation of the EC on the governance structure of the FCH JU, the experts decided to interview one or two persons from all of the different bodies and institutions involved in order to have a representative sample of the FCH JU. Some of the experts personally knew the interviewees from their own, previous involvement in EU H & FC institutions and projects.

The list of persons that have been interviewed is attached to the final evaluation report. All of the persons interviewed were somehow involved in the governance of the FCH JU, be it as members of the Governing Board, chairmen of the working groups in the NEW IG or the N.ERGHY Research Grouping, direct employees of the FCH JU such as the Executive Director and the staff of the Programme Office, or as coordinators of projects funded by the

FCH JU. In addition, seven members of the States Representatives Group have been interviewed (European Commission 2011d, 18–24). The secretary team of the EC contacted the persons that the expert panel had selected as desired interviewees and facilitated the interviews so that most of these could be conducted over two days in early March 2011 in Brussels. Before the physical interviews were conducted, the interviewees have been sent the list of questions per email and responded to these in written form, too. Some of the interviewees could not be physically present in Brussels so that they these interviews were conducted over the telephone.

The expert panel decided on its own whether it wanted to interview further persons or whether it needed to collect further data in the form of reports and studies. For instance, in order to assess the stage in development of H & FC and the work of the States Representatives Group, the experts decided to pose further questions to the industrial actors of the NEW IG and to conduct further interviews with some of the members of the States Representatives Group. The expert panel also decided to interview other actors in the field of H & FC that were not directly involved in the FCH JU such as the vice-chairman of the organization of the European regions for the development of H & FC, HyRaMP, in order to get the view of external actors on the FCH JU. Furthermore, the expert panel requested and received some internal documents on the work of the FCH JU such as evaluation reports of calls for proposals or records of the decisions taken at the meetings of the Governing Board.

### 8.3.4 The compilation of the first interim evaluation report

After the conduct of the interviews the experts discussed and analyzed the data collected. These discussions revealed a number of divergent opinions on various issues such as the effectiveness or the quality of the FCH JU. Therefore, several draft reports have been written and the experts had a lot of discussions with each other and also a lot of exchange via emails before they could reach a consensus on specific issues. Furthermore, the expert panel identified several problems in the operation of the FCH JU that it wanted to illustrate in the final report. Therefore, the experts discussed how this could be done in a helpful way so that the critique is read as constructive recommendations that eventually lead to an improvement of the flaws detected.

The expert panel performed the analysis of the data collected and the compilation of the first drafts on its own. First, as the expert panel thought to be progressing towards the final version of the evaluation report the officials of the EC involved in the FCH JU wanted to participate in the meetings so that they could comment on the main conclusions drawn and discuss these with the experts. The EC representatives double-checked the final version of the evaluation report on any potential formal mistakes such as for instance stating the wrong date of the official launch of the FCH JU. Hence the role of the EC was partly to ensure that the final version of the evaluation report fits into the general pattern of how an evaluation report of the EC on the JTIs should look like.

Furthermore, the officials of the EC and the expert who was also involved in the expert panels on the evaluation of the other JTIs made sure that the drafts of the evaluation report are set up in a similar structure as the evaluation reports on the other JTIs. While for instance the expert panel had to report on the criteria of effectiveness, efficiency, and quality of the FCH JU which were defined by the EC on the basis of experiences in evaluations of other JTIs, the experts decided on their own to conduct a SWOT analysis and to include it in the final version of the evaluation report. Similar structures of the evaluation reports were important to the officials of the EC because after the completion of these they were to comment on all of the different evaluations and the recommendations included in a Commission Staff Working Paper (European Commission 2011e) that was to accompany the EC's Communication "Partnering in Research and Innovation".

The officials of the EC also assisted the expert panel in developing the recommendations in the final version of the evaluation report. This worked in the way that the experts reported the problems they had identified to the EC so that both together discussed what could be reasonably done to solve these problems in order to formulate the recommendations for the evaluation report. These discussions focused on the feasibility of what actually can be done in the scope of the FCH JU. While the experts had many ideas of what could be done to improve the FCH JU, they also wanted to formulate practical recommendations that actually could be implemented with regard to legal, financial and other constrains. The officials of the EC provided advice in this respect as illustrated in the following quotation of a member of the expert panel:

> "I mean we as persons coming from everywhere can also have ideas about how things should be runned but the Commission said that we should stick to the rules and so we could not include a recommendation that was not possible if it is absolutely not feasible or not practical or if there are legal restraints for example than there is no point to make such recommendations in the report. So it was quite helpful in the end to have that because we wanted to have also practical recommendations and not just to blow up our heads with the good ideas." (Interviewee 12, 2012)

However, the officials of the EC did not only correct formal mistakes and provide practical advice but also exerted influence on the conclusions drawn in the report to a certain extent. Above all the officials from the higher hierarchical levels of the EC wanted to be able to react on the conclusions drawn by the expert panel and to give their own opinion on these conclusions so that the experts could take the EC's opinion into account, too, and potentially modify its recommendations or just the specific formulations used. The first drafts of the evaluation report for instance included some harshly formulated critique against which the high-ranking officials of the EC defended themselves. Some of them experienced the critique on the operation of the FCH JU as unfair and disagreed with it. For this reason, they outlined their view on the FCH JU to the expert panel.

Hence the high-ranking officials of the EC and the expert panel had a thorough discussion on the outcomes of the evaluation of the FCH JU before these were published.

The officials of the EC had access to the data collected and, of course, also to all of the interviewees as the interviews had been facilitated by the policy and scientific officers of the EC. If the officials of the EC disagreed with the illustration of a specific issue in the draft of the evaluation report, for example because they felt that the presentation was unbalanced or plain simply not correct, then they uttered this view. In doing so, the high-ranking officials of the EC advocated their view of the FCH JU to the expert panel and exerted a degree of pressure on the experts to adopt this view.

The officials of the EC also brought some issues into the discussion that might not have been raised by the members of the expert panel on their own. An important issue that was brought into the discussions with the expert panel by the officials of the EC was for instance whether it should be recommended to continue the FCH JU or not. This issue arose because the evaluation was conducted in 2011 so that the discussions on FP 8 that was to start in 2014 had already begun. Consequently, it was an important question for the EC whether the expert panel would recommend continuing the FCH JU in FP 8 or whether it would conclude that the FCH JU is not working effectively and should be shut down.

In the end the expert panel recommended to continue the FCH JU as can be seen in the evaluation report (European Commission 2011d, 18–24). This conclusion was not an obvious one because some members of the expert panel were rather sceptical on H & FC as there were no products on the market yet so that H & FC could not be seen anywhere. However, in the view of the officials from the higher hierarchical levels of the EC the FCH JU should be continued in Horizon 2020 and thus they outlined this view to the members of the expert panel. As a result, the experts decided to conduct further investigations and interviews with, above all, industrial actors to find out what stage in development H & FC have reached and how long it would take to see the first products on the market. Eventually, the members of the expert panel concluded that there are serious ambitions to commercialize H & FC and thus they agreed upon recommending continuing the FCH JU to further support this development.

However, the high-ranking officials of the EC were not the only ones who discussed the potential outcomes of the evaluation with the expert panel but also the representatives of the private enterprises were involved and tried to influence the evaluation to a certain extent. It was for instance discussed whether an amendment of the Multi Annual Implementation Plan of the FCH JU should be recommended in the evaluation report or not. The members of the expert panel had been looking on the development of H & FC in other countries such as China, Japan, South Korea, and the USA and they got the impression that H & FC are being developed in a more target-oriented way in some of these countries. Therefore, the experts thought of suggesting that the FCH JU should regularly reconsider its Multi Annual Implementation Plan in order to ensure that the objectives pursued are still relevant and in order to increase the ability of the FCH JU to react on important developments such as technology breakthroughs elsewhere.

The suggestion of a regular revision of the Multi Annual Implementation Plan, however, caused opposition from the industrial actors interviewed for the evaluation. Indeed, many actors in the FCH JU were opposed to a revision of the Multi Annual Implementation Plan as this would imply new, time-consuming and exhausting negotiations on the distribution of the funding available. Many of these actors were happy that a compromise on the issue could be reached and they were not willing to start the discussions anew. However, the expert panel stuck with its opinion and suggested a revision of the Multi Annual Implementation Plan in the final evaluation report.

In sum, the outcomes of the first interim evaluation of the FCH JU resulted from the discussions of the expert panel with the high-ranking officials of the EC and the representatives of private enterprises. A member of the expert panel described these discussions in the following way: “So it was a very open working process but it was also made quite clear that it was up to the expert panel to decide what we should conclude and recommend” (Interviewee 12, 2012). This quotation indicates that the final decisions on what would be concluded and recommended in the evaluation report were made by the members of the expert panel. However, the preceding paragraphs have also illustrated that different actors attempted to influence the decisions of the expert panel. Above all the officials from the higher hierarchical levels of the EC exerted a degree of pressure on the expert panel to recommend the continuation of the FCH JU in the evaluation report. Hence, while it could not be elaborated in this thesis in how far this pressure actually did influence the final decisions of the expert panel, the main point was to highlight that different actors attempted to do this and exerted a degree of pressure on the members of the expert panel.

### 8.3.5 Consequences of the evaluation: The revision of the Multi Annual Implementation Plan

In response to the evaluation reports on three of its JTIs, among which the FCH JU, the EC published a Commission Staff Working Paper summarizing the findings, recommendations and conclusions of the evaluations and presenting its own view on these. Basically the EC agrees with all of the recommendations made by the expert panel and assures to work on the changes required within its powers (European Commission 2011e, 16–21). As the data collection for this thesis was conducted shortly after the interim evaluation of the FCH JU, it could not be elaborated in how far the long-term recommendations on the development of an effective communication strategy for the FCH JU and the improvement of the work of the States Representatives Group have actually been implemented. In contrast, the Multi Annual Implementation Plan of the FCH JU was revised as recommended only a few months after the interim evaluation was completed as will be illustrated in the following paragraphs.

In fact, the Multi Annual Implementation Plan was revised by the NEW IG and the N.ERGHY Research Grouping. The Governing Board approved the revised version on 22 November 2011. Apart from the general updates such as on the inclusion of the N.ERGHY Research Grouping as a founding member of the FCH JU and the completed selection of the staff for the Programme Office, the Multi Annual Implementation Plan was largely kept as it was and only small revisions and updates have been carried out. The distribution of the funding available among the different areas of application for instance has been kept unchanged (Fuel Cells and Hydrogen Joint Undertaking 2009, 8, 2011c, 9). Also the description of the four main areas of application has been kept mostly unchanged with only minor revisions and updates (Fuel Cells and Hydrogen Joint Undertaking 2009, 11-16, 2011c, 12-18).

However, as demanded by the evaluation report, more emphasis was laid on the development of regulations, codes, and standards. In the revised Multi Annual Implementation Plan the FCH JU dedicates a subsection to the description of its strategy for the development of regulations, codes, and standards (Fuel Cells and Hydrogen Joint Undertaking 2011c, 18). Furthermore, the subsection on the interfaces with other EU policies has been updated and considerably expanded so that H & FC are embedded in the most recent developments in EU energy, innovation, and transport policy (Fuel Cells and Hydrogen Joint Undertaking 2011c, 23, 24).

The revised Multi Annual Implementation Plan also lists much more distinguished objectives and technical targets for the years 2015 and 2020. While the initial Multi Annual Implementation Plan listed a few concrete technical targets for each of the four main areas of application (Fuel Cells and Hydrogen Joint Undertaking 2009, 7), the revised one establishes concrete targets for very specific technologies inside of the four main areas of application. In the area of stationary applications for instance it is distinguished among natural gas based micro combined heat and power applications, hydrogen based industrial or commercial applications, and natural gas based industrial or commercial applications. For each of these three areas concrete numbers are listed in terms of units sold and price per system as envisioned for the years 2015 and 2020 (Fuel Cells and Hydrogen Joint Undertaking 2011c, 7, 8). In addition, the revised Multi Annual Implementation Plan includes an annex with even more distinguished technological areas inside of the main areas of application and specific technical targets (Fuel Cells and Hydrogen Joint Undertaking 2011c, 34-42).

## 8.4 Conclusions

This chapter explained the implementation and the first interim evaluation of the FCH JU from the theoretical perspective applied in this thesis. Based on the empirical data collected, it was highlighted that the co-production of EU H & FC policy and expertise in the years of 2007-2011 was most influenced by the policy stages of implementation and evaluation of the wider EU R&I policy. The implementation of the FCH JU was characterized by competition in the distribution of the resources that the launch of a JTI for H & FC brought about. The different actors from the EC, from private enterprises, and from public research institutes that had previously argued in common for setting H & FC on the agenda and for launching the JTI for H & FC, competed with each other for influence and power in the implementation of the FCH JU. The different private enterprises and public research institutes competed with each other in securing the highest amount possible from the overall budget of the FCH JU to their technological area of interest. For this purpose, all of the different actors involved used specific expertise on H & FC in order to highlight the importance of their technological area of interest for the overall development of H & FC. In addition, the officials of the EC competed with the private enterprises in securing their influence on the development of H & FC in the governance structure of the FCH JU.

These struggles for a high share of the budget of the FCH JU and for influence in the development of H & FC were affected by the resources available to the different actors and by the EC's general understanding of innovation and its focus on competitiveness. In the view of many officials of the EC the FCH JU should be led by the industrial companies involved in order to push H & FC towards commercialization and to increase the competitiveness of the European industry. In addition, the large private enterprises involved possessed the necessary resources to employ one or more persons who would dedicate their time to asserting their views in the implementation of the FCH JU. In contrast, the public research institutes and universities involved did neither possess the resources to allow their employees to dedicate a good part of their time to the implementation of the FCH JU nor the financial means to lead H & FC to commercialization. Hence the implementation of the FCH JU was mainly led by the representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities and the officials of the EC.

However, while the high-ranking officials of the EC at the Director and Director-General level agreed that the industry should play a leading role in the development of H & FC, they refused to cede the decisions on the budget of the FCH JU to the industrial actors involved. Therefore, the officials of the EC ensured that they have a veto right on all decisions concerning the distribution of the budget of the FCH JU. In so doing, the officials of the EC attempted to keep control over the spending of public money in order to avoid fraud. This ambition of the officials of the EC to keep control over the spending of public money caused a fundamental contradiction in the implementation of the FCH JU as most of the decisions on the further development of H & FC inevitably also concern the distribution of the budget available. Hence the industrial actors involved cannot really lead the development of H & FC if they do not have the final say over the decisions concerning the financial resources of the FCH JU. This contradiction was never fully resolved during the implementation of the FCH JU and gave rise to controversy between the officials of the EC and the representatives of the industry over several issues such as the procedures for the assessment of the project proposals for funding submitted to the FCH JU.

Furthermore, the actors involved perceived two main problems in the implementation of the FCH JU. First, the establishment of the FCH JU as an autonomous organization with its own staff took more than two years which resulted in the FCH JU not being able to operate as it should. This delay was partly caused by the regulations of the FCH JU which demanded to apply the complex general EU regulations for the recruitment of staff and partly by different views of the EC and the industrial companies on what persons should be recruited and what their specific tasks should be. Second, the specific regulations of the FCH JU resulted in funding rates that were lower than in the usual research projects funded in the FPs of the EC. This caused above all complaints from the public research institutes involved in the FCH

JU. Eventually, the funding rates were amended which led to a slight improvement although they remained lower than in the usual research projects funded in the FPs.

The first interim evaluation of the FCH JU was part of the overall evaluations of the JTIs of FP 7 which were shaped by the bureaucratic logics of the EC as a public administration. All evaluations were conducted by expert panels whose members were appointed by the officials of the EC according to the EC's general criteria for the selection of experts (European Commission 2010c, 10, 11). For the internal purposes of a public administration the officials of the EC ensured that all JTIs are evaluated by similar criteria so that the results of the evaluations of the different JTIs would allow a comparison of the operation of the different JTIs. Furthermore, the officials of the EC asked the expert panels to develop recommendations on the improvement of the different JTIs and to evaluate whether they would recommend a continuation of the JTI in question or not. These recommendations were to be used in the further policy process and in the negotiations of the eighth FP which were to start soon after the evaluations had been completed.

Hence the first interim evaluation of the FCH JU was conducted together by an expert panel and the officials of the EC. However, the officials from the higher hierarchical levels of the EC did not only ensure that the evaluation is conducted according to the bureaucratic needs of the EC as a public administration but they also attempted to influence the outcomes of the evaluation to a certain extent. Indeed, if the officials of the EC disagreed with the expert panel's findings on the operation of the FCH JU, they illustrated their own views on the FCH JU to the members of the expert panel. In so doing, the officials of the EC exerted a degree of pressure on the members of the expert panel to adopt the views on the FCH JU presented to them and to recommend the continuation of the FCH JU in the eighth FP. Due to this pressure from the high-ranking officials of the EC, the members of the expert panel decided to conduct further investigations on the development and the future prospects of H & FC. Eventually, the members of the expert panel came to the conclusion to recommend the continuation of the FCH JU. This recommendation was used by the officials of the EC in the negotiations of Horizon 2020 in order to legitimize the continuation of the FCH JU as will be illustrated in the next chapter.

# 9 2011 - 2014: Ensuring a Joint Technology Initiative for H & FC in Horizon 2020

This chapter explains the co-production of EU H & FC policy and expertise in the years of 2011-2014 which resulted in the continuation of the Joint Technology Initiative for H & FC in Horizon 2020. For this purpose, the policy cycle model was applied in order to outline the most important issues in the co-production of EU H & FC policy and expertise at that time. Based on the empirical data collected for this thesis, the chapter at hand illustrates that the co-production of EU H & FC policy and expertise in the years of 2011-2014 was most influenced by the policy stages of agenda-setting and decision-making. The main point is that the co-production of EU H & FC policy and expertise was part of the broader negotiations of Horizon 2020 in which the EC had to decide what technologies were to be part of its research and innovation agenda for Horizon 2020 and what policy instruments should be applied for the promotion of these technologies. Consequently, many of the actors involved in the implementation of the different policy instruments in FP 7 attempted to ensure that their technological areas of interest would be further promoted in Horizon 2020. For this purpose, they attempted to raise political attention to their technological areas of interest and to legitimize their continued promotion by highlighting the specific role of these technologies for the achievement of the broader policy objectives of the EU such as economic growth, fighting climate change, etc.

Also the actors involved in the FCH JU were part of these general preparations of Horizon 2020 and attempted to ensure the further promotion of H & FC in FP 8. After the establishment the FCH JU as a working organization with its own staff had been completed in 2011, the actors involved turned their attention towards keeping H & FC on the European agenda and legitimizing the continuation of the FCH JU in Horizon 2020. For this purpose, they negotiated a new H & FC development programme and highlighted the specific importance of H & FC for the achievement of the broader objectives of EU innovation, energy, and transport policy. In addition, the expertise required to outline the specific role of

H & FC in relation to other alternative drivetrain technologies and fuels was developed and promoted in different expert authorities of the EC. With the help of this expertise, the continuation of the FCH JU in Horizon 2020 was legitimized in an Impact Assessment and in the wider policy discourse.

This chapter is split into four subchapters in order to explain the co-production of policy and expertise that eventually resulted in the launch of a modified FCH JU, the FCH 2 JU, in May 2014 in more detail. First, it is explained how the co-production of EU H & FC policy and expertise has been part of the general preparations of Horizon 2020 and shaped by these. Second, it is outlined how a new European H & FC development programme was negotiated and how the expertise required for raising political attention to H & FC and for legitimizing the continuation of the FCH JU was produced. Third, it is illustrated how the expertise produced was transferred into the policy discourse and used to defend H & FC against its critics and to justify the continuation of a modified FCH JU in the broader policy discourse and in the Impact Assessment. Finally, the most important findings of this chapter are summed up.

## 9.1 H & FC in the preparations of Horizon 2020

As will be demonstrated throughout this chapter, the empirical data analyzed in this thesis point out that the co-production of EU H & FC policy and expertise in the years of 2011-2014 was embedded in the preparations of Horizon 2020 and influenced by these. At that time the EC was negotiating the new research and innovation agenda that was to be pursued in its eighth Framework Programme and deciding upon what research and technological areas will be further promoted by what policy instruments. The supporters of different technologies that were promoted in FP 7 attempted to keep their technological area of interest on the European agenda and to ensure its further promotion in Horizon 2020. In addition, the supporters of other technologies that have not been promoted in previous FPs of the EC attempted to raise attention to these technological areas in order to make them part of

Horizon 2020. Therefore, the wider EU R&I policy most resembled the stages of agenda-setting and decision-making of the policy cycle model in the first years of the second decade of the new millennium.

Also the co-production of EU H & FC policy and expertise was influenced by this broader discourse on EU R&I policy as the supporters of H & FC attempted to keep these technologies on the European research and innovation agenda and to achieve a continuation of the FCH JU. Consequently, the co-production of EU H & FC policy and expertise was shaped by the stages of agenda-setting and decision-making in the wider EU R&I policy and expertise had to be developed to raise attention for H & FC and to justify the continuation of the FCH JU in Horizon 2020. Therefore, the following paragraphs are to briefly outline the most important issues that have characterized the preparations of Horizon 2020 and shaped the co-production of EU H & FC policy and expertise in the years of 2011-2014.

What the Lisbon Agenda was for the first decade of the new millennium, Europe 2020 was to be for the second one. The EC published its Communication "Europe 2020. A strategy for smart, sustainable and inclusive growth" in 2010 outlining the three key priorities of its vision of Europe 2020: 1) Smart growth and the development of an economy based on knowledge and innovation, 2) Sustainable growth and the promotion of a more resource efficient, greener and more competitive economy, and 3) Inclusive growth fostering a high-employment economy delivering social and territorial cohesion (European Commission 2010a, 5). In fact, Europe 2020 is the successor of the never really fulfilled Lisbon Agenda that should make the EU to the most competitive and dynamic knowledge-based economy in the world. Consequently, innovation is also one of the main priorities of Europe 2020.

Indeed, the Innovation Union is one of the seven flagship initiatives which the EC describes as its key means to achieve the objectives of Europe 2020 (European Commission 2010a, 5, 6). In its Communication "Europe 2020 Flagship Initiative Innovation Union" in 2011 the EC describes innovation as the best means to fight the crisis. While the EC's understanding of innovation has been broadened a little in comparison to the Lisbon Agenda and now includes many more social and welfare aspects, the main focus is still on maintaining “the economic foundation that supports our quality of life and our social model as our population ages” (European Commission 2011a, 4). Hence the EC’s notion of innovation has been broadened but it still maintained its primarily economic focus.

Furthermore, the EC’s understanding of innovation was still closely tied to its idea of competition with other countries. For instance, one of the arguments for the promotion of the innovation union was that the annual EU investment in R&D in percentage of the GDP is by 0.8 % less than that of the USA and by 1.5 % less than that of Japan (European Commission 2011a, 8). In addition to the USA and Japan outperforming the EU in innovation, other countries such China and South Korea are catching up quickly which increases the urgency for the EU to improve its innovation performance (European Commission 2011a, 8, 39, 40). Consequently, the EU was in need to increase its global competitiveness and its innovation performance.

In addition, the negotiations on Horizon 2020, the EC’s eighth Framework Programme, took place in the light of the sovereign debt crisis. Against the background that many Member States wanted to reduce their financial contributions to the EU, the promoters of Horizon 2020 had to argue for their share of the overall multiannual financial framework of the EU. In addition, the promoters of different technologies and research programmes had to fight for their share within Horizon 2020. Consequently, the supporters of different technologies attempted to highlight the importance of their technologies preferred for the three key priorities of Horizon 2020: 1) Excellent Science, 2) Industrial Leadership, and 3) Societal Challenges (European Commission 2011b, 4, 5).

The second priority of industrial leadership was, among others, to be promoted through the launch of public private partnerships with the European industry. In addition to the continuation of the existing five Joint Technology Initiatives at that time, the EC also discussed the launch of contractual public private partnerships (European Commission 2013g). In contrast to JTIs, the contractual public private partnerships were not to organize their own calls for project proposals for funding but rather the EC would organize these calls under the Horizon 2020 work programme (European Commission 2013g). This illustrates that the application of public private partnerships for the promotion of specific technological areas has been a popular idea in the negotiations of Horizon 2020 in the years of 2011-2014.

Hence the issues that were briefly outlined in the preceding paragraphs characterized the general preparations of Horizon 2020 in which the proponents of different technologies attempted to raise attention for their technological area of interest in order to secure the promotion of this technological area in FP 8. Also the co-production of EU H & FC policy and expertise was embedded in these negotiations of Horizon 2020 and thus shaped by the broader discourse on EU R&I policy as will be explained in more detail in the following two subchapters. First, in subchapter 9.2 it will be outlined how the expertise required for raising political attention for H & FC and for justifying the continuation of the Fuel Cell and Hydrogen Joint Undertaking was produced. This includes the definition of a new H & FC development programme that was to be pursued in the eighth Framework Programme. Second, subchapter 9.3 will illustrate how the expertise produced was fed into the policy discourse in order to justify the continuation of the Fuel Cell and Hydrogen Joint Undertaking and to H & FC defend it against its critics.

## 9.2 The expertise discourse: Negotiating a European H & FC development programme and producing the expertise for its legitimization

This subchapter explains how the expertise required for raising political attention for H & FC and for justifying the continuation of the Fuel Cell and Hydrogen Joint Undertaking was produced. The interpretations of the interviews conducted for this thesis have revealed that the production of expertise was mainly led by specific policy entrepreneurs which possessed the necessary resources to assert their views on H & FC. These policy entrepreneurs were high-ranking officials of different DGs of the EC including the JRC and representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities who were supportive of H & FC and attempted to ensure the continuation of the FCH JU in

Horizon 2020. Due to their resources such as their own hierarchical position in the EC and the time and financial means available to them, these policy entrepreneurs could influence the production of expertise on H & FC more than other actors such as the scientist of public research institutes and the representatives of smaller companies. Their resources enabled the policy entrepreneurs not only to assert their views on H & FC in the production of expertise as will be outlined in the following paragraphs but also to feed this expertise into the policy discourse and to use it to legitimize the continuation of the FCH JU in Horizon 2020 as will be outlined in the next subchapter.

In order to fully account for the different developments in the expertise discourse on H & FC in the years of 2011-2014 the subchapter at hand is split into three parts. First, it is explained how the different supporters of H & FC negotiated a European H & FC development programme that should be pursued by a continued FCH JU in the eighth Framework Programme of the EC. Thereafter, it is illustrated how the different supporters of H & FC produced the expertise required to promote their view on H & FC in the different expert authorities of the EC which were defining the future prospects of different alternative energy technologies. Finally, it is highlighted how the different supporters of H & FC situated these technologies in Horizon 2020 in order to legitimize the continuation of the FCH JU.

### 9.2.1 Defining a European H & FC development programme for Horizon 2020

This subchapter describes how the European H & FC development programme that was to be implemented in Horizon 2020 was negotiated by the different actors involved in the FCH JU. The empirical findings of this thesis show that these negotiations were dominated by industrial companies and above all by large private enterprises who not only possessed the necessary resources to assert their views on H & FC but whose views were also supported by the understanding of innovation of the officials of the EC that were involved in the discussions. In this understanding innovation was primarily conceived of as the development of new commercial products which supported the view of the industrial companies who argued that the new FCH JU in Horizon 2020 should focus on the further development and commercialization of existing and proven technologies. Simultaneously, this understanding of innovation made it difficult for public research institutes and universities to assert their view of a new FCH JU that should focus more on basic research.

The following paragraphs are to illustrate in more detail how these conclusions were reached through the interpretation of the empirical data collected for this thesis. First, the European H & FC development programme negotiated for Horizon 2020 will be illustrated. Thereafter, it will be explained how the development of this programme was mainly led by the industrial companies of the NEW IG while the public research institutes and universities only played a minor role and therefore tried to secure a separate programme for basic research on H & FC in Horizon 2020 outside of the FCH JU.

*The European H & FC development programme for 2014-2020*

The European H & FC development programme that was negotiated for the time period of 2014-2020 is well illustrated in the report “The Financial and technology outlook on the European H & FC sector 2014-2020”. This report was compiled by the private enterprises organized in the NEW IG in coordination with N.ERGHY, the association of the public research institutes and universities, with HyRaMP, the association of the European regions interested in H & FC, and with the European Hydrogen Association (NEW Industry Grouping 2011b, 7). The report outlines the financial resources required to commercialize H & FC until 2020 as estimated by the actors involved and illustrates the technical objectives to be reached by 2020.

It is estimated that € 17.9 billion will be required in the years of 2014-2020 in order to achieve a technology breakthrough in H & FC. These € 17.9 billion are to be distributed among the four areas of application of 1) transport and refuelling infrastructure, 2) hydrogen production, 3) stationary fuel cells, and 4) early market applications with € 300 million going to the additional activities in the development of regulations, codes, and standards. Inside of the different areas of application, three main types of activities are distinguished: 1) Research and development, 2) Demonstration programmes, and 3) Market introduction support (NEW Industry Grouping 2011b, 9, 10).

The largest part of the total sum of € 17.9 billion that is to say € 12.1 billion is to be dedicated to the application area of transport and refuelling infrastructure. Of these € 12.1 billion within the application area of transport and refuelling infrastructure, € 0.5 billion are to be dedicated for research and development, € 2.2 billion are reserved for demonstration programs, and the largest part of € 9.4 billion are to be invested in market introduction support. Hence more than half of the total sum of € 17.9 billion is foreseen for market introduction measures in the application area of transport and refuelling infrastructure. These market introduction measures in the application area of transport and refuelling infrastructure refer above all to the enlargement of the car fleet and the built-up of a refuelling infrastructure (NEW Industry Grouping 2011b, 26).

The financial and technology outlook also illustrates the more concrete technical objectives that are to be achieved by 2020. There are to be 500,000 fuel cell vehicles on the street and at least 1000 hydrogen refuelling stations supplying these vehicles with hydrogen. It is envisioned to produce 50% of the hydrogen required from renewable energies or in other ways that do not cause any $CO_2$ emissions. Hydrogen is going to be used as a storage medium for the electricity generated from renewable energies in a capacity up to 500 megavolts. In the stationary sector 50,000 households are to provide heat and power by fuel cells (NEW Industry Grouping 2011b, 25).

In addition to outlining the envisioned H & FC development for 2014-2020, the report also states that the industrial companies involved are willing to invest double or three times as much as the EC and the Member States together in the development of H & FC in the years of 2014-2020. This commitment is underpinned by concrete numbers as it is estimated in the report that a total EC contribution of approximately € 2.5 to € 4 billion together with the investments of national and regional authorities of around € 2 to € 4 billion would result in investments of € 10 to € 14 billion from the private sector (NEW Industry Grouping 2011b, 34). This commitment of the private sector was to play a role in the negotiations of the continuation of the FCH JU as the existence of a committed industrial sector is one of the conditions that have to be fulfilled for the establishment of a JTI according to the formal regulations of the EC (European Commission 2005a, 10).

*The negotiations of the European H & FC development programme for 2014-2020*

The empirical data collected for this thesis outline that the negotiations of the European H & FC development programme were dominated by the industrial companies of the NEW IG. In their view the future FCH JU in Horizon 2020 should focus on further improving the existing H & FC technologies in order to bring these to the market as quickly as possible. This view was supported by the officials of the EC involved in the negotiations due to their primary understanding of innovation as the development of new commercial products. Consequently, the bulk of the total sum requested for the development of H & FC in the years of 2014-2020 was foreseen for market introduction measures. This caused opposition from the public research institutes involved in the FCH JU who, according to several interviews conducted for this thesis, argued for an increased role of basic research in the development of H & FC (Interviewee 8, 2012; Interviewee 11, 2013; Interviewee 18, 2012). However, as it became clear that basic research will continue to play only a minor role in the new FCH JU the public research institutes and universities began to promote the idea of a separate programme for basic research on H & FC in Horizon 2020. The following paragraphs will outline the different arguments put forward in the negotiations of the European H & FC development programme in more detail. However, whether or not a separate programme for basic research on H & FC was actually realized cannot be elaborated at this point as the discussions on the work programmes of Horizon 2020 have not been finished while this thesis was written.

First, the public research institutes attempted to increase the role of basic research on H & FC in the new FCH JU in Horizon 2020 by arguing that it is part of the overall value chain and thus should receive more funding than it has received in the past. The main argument of the public research institutes and universities was that there are a lot of issues that are not covered by the FCH JU because it focuses too much on the further improvement of existing technologies. Therefore, the FCH JU does not fund specific breakthrough technologies that, although still far away from commercialization at the moment, might be a better solution than some of the existing technologies in the future. The issue of a new type of Solid-Oxide Fuel Cells was for instance used as an example of how breakthrough technologies are excluded from the FCH JU as the following quotation of a scientist of a public research institution illustrates:

> "All the topics in the JTI are focused on to improve the durability of the existing architecture of the Solid-Oxide Fuel Cell. We have the example of very innovative architecture of SOFC, quite new, it is not included in the JTI. You have to proof the feasibility, typically this work is breakthrough because its colleagues from different countries, it is a very quiet design of Solid-Oxide Fuel Cells because of five layers instead of three because they separate different effects, water and so on. There is some advantage but it is only at the stage of the laboratory demonstration and this type of technology is not included in the Multi Annual Implementation Plan, for example. So the Multi Annual Implementation Plan is excluding these types of technologies because we have no time in the JTI to make all the steps. It will probably take five years to make different projects, to have a sort of prototype and so on before it enters in this area." (Interviewee 8, 2012)

However, the private enterprises of the NEW IG emphasized that the FCH JU should be an industry-led public private partnership that focuses on applied research and demonstration in order to bring products onto the market. Thus the upcoming FCH 2 JU should be even more focused on deployment and pre-commercialization as the way of bringing H & FC to the market should be continued. This line of argumentation was also supported by the officials of the EC who see the FCH JU as a policy instrument that is to bring about innovation in the form of new commercial products on the market. Thus the amount of funding dedicated to basic research on H & FC in the new FCH JU in Horizon 2020 was to be kept at a rather low level compared to the sum dedicated to support market introduction measures.

As a result, the public research institutes and universities began to promote the idea of a complementary programme to the FCH JU in Horizon 2020 that is more focused on the breakthrough technologies that will not be funded by the FCH JU. In fact, already in FP 7 some research projects on breakthrough technologies in the area of H & FC have been funded within the Future Emerging Technologies scheme of the broader theme of nanosciences, nanotechnologies, materials, and new production technologies. Therefore, the public research institutions suggested having a Future Emerging Technologies scheme with an increased focus on energy technologies in Horizon 2020. This new programme should include breakthrough research on H & FC and run in parallel to the new FCH JU in a complementary manner. For this purpose, the new Future Emerging Technologies scheme should maintain close ties to the new FCH JU so that their complementary nature is ensured. The public research institutions advocated this idea in the EP and in the EC in order to raise support for it.

The following quotation of an official of the EC exemplifies the debate on basic and applied research that was led between the industrial companies and the public research institutions in the negotiations of the new FCH JU:

> “Should basic research be included in the FCH JU or not? And this has been a long debate. Some argue that it is part of the value chain so it should be, others say that the FCH JU is an industry-led partnership so it is more applied research and demonstration while basic research is by nature a bit more horizontal so it should be more in the Framework Programme in the Nano Materials Programme. So we will do a bit of focused topics of basic research in the FCH JU but it is true that Nano Materials

> Programme will keep a lot of it and we will focus more on applied. … The research community, the universities, they want to make sure that they will have some allocation of funds so if we put that in the FCH JU they would be okay but the industry does not want to spend a lot of the resources of the FCH JU on basic research but rather the industry wants demonstration. How should it be balanced? I think it should be in the Nano Materials Programme, in the Work Programmes, they should have something." (Interviewee 11, 2013)

The quotation above also indicates that the officials of the EC were in principle open to the idea of including basic research on H & FC in other funding schemes of Horizon 2020. However, it was also made clear that there would not be a separate programme focusing exclusively on basic research on H & FC but rather project proposals on breakthrough research on H & FC would have to compete with project proposals on other technologies in the usual funding schemes of Horizon 2020. Many of these funding schemes were to be technology neutral which is to say that projects would be selected for funding according to the purposes which they promise to fulfil. Hence project proposals on H & FC would have to compete with proposals on related technologies that promise to fulfil the same objectives as the following quotation of an official of the EC illustrates:

> "Future Energy Technologies is a technology neutral programme. Propose me a FET, not necessarily H & FC, propose me photosynthesis, electrochemistry, whatever crazy idea that can produce electricity and if it is H & FC then it is good, there we go. … Some in the research community may have wanted their own FET for basic research but that cannot be done because you need to have more competition. You cannot reserve money for everybody because you need competition." (Interviewee 11, 2013)

However, in how far basic research on H & FC will be included in the different funding schemes of Horizon 2020 cannot be clarified at this point as the negotiations on the concrete funding schemes of Horizon 2020 have not been finished, yet, while this thesis was written.

In any case, the main point of this subchapter was to explain the how the different actors involved negotiated a new European H & FC development programme that was to be implemented by the new FCH JU in Horizon 2020. Subsequently, the following subchapter will explain how the expertise required for justifying the continuation of the FCH JU in Horizon 2020 was developed and anchored in the different expert groups of the EC and the JRC.

### 9.2.2 Developing expertise for justifying the continuation of the FCH JU and establishing it in different expert authorities of the EC

In order to justify the continuation of the FCH JU in Horizon 2020 the future potential of H & FC was demarcated against that of other alternative drivetrain technologies and fuels. For this purpose, the different supporters of H & FC first developed specific expertise that highlights the advantages of H & FC over battery electric vehicles and plug-in hybrids and outlines a specific role for H & FC vehicles in a future emission-free transport system. In a nutshell, the main argument was that there is no competition between the different drivetrain technologies and fuels but rather all three of them will be needed as they serve different segments of the car market due to their specific technical properties. H & FC for instance were to be best suited to power large passenger cars and to cover longer driving ranges.

Thereafter, this expertise was promoted in different expert authorities of the EC such as the Strategic Energy Technologies Information System and the Expert Group on Future Transport Fuels in order to establish the view of a complementary relationship between the three different drivetrain technologies and fuels. By establishing the view of a complementary relationship between the three different drivetrain technologies and fuels in these expert authorities, the expertise developed by the supporters of H & FC was further validated and stabilized. In this way the supporters of H & FC made sure that their complementary view on the different drivetrain technologies and fuels is established in the most important sources of expertise that the policy-makers of the EC would consider when deciding upon what technologies are to be promoted by what policy instruments in Horizon 2020.

The following paragraphs are to describe these developments in more detail. First, it is outlined how the different supporters of H & FC developed the expertise that outlines a complementary relationship between the different drivetrain technologies and fuels. Second, it is explained how this expertise was established in different expert authorities of the EC such as the Strategic Energy Technology Information System which is managed by the JRC and the Expert Group on Future Transport Fuels.

*Defining a specific role for H & FC in relation to other alternative drivetrain technologies and fuels*

The different supporters of H & FC were involved in the expertise discourse to different extents and their impact on the development of expertise on H & FC varied considerably. However, in contrast to the negotiations of a European H & FC development programme for Horizon 2020 in which different actors promoted diverging views as outlined in the preceding subchapter, the development of expertise for defining a specific role for H & FC in relation to other alternative drivetrain technologies and fuels was guided by the shared objective of keeping H & FC on the European agenda. Hence, while some actors were more active than others in the production of expertise, the expertise that was developed in the end outlining a complementary relationship between the different drivetrain technologies and fuels was shared by the different actors involved in the expertise discourse on H & FC.

The following paragraphs will focus on illustrating how two of the most influential groups of actors developed the expertise outlining a complementary relationship between H & FC vehicles, battery electric vehicles, and plug-in hybrids. These two groups of actors are the representatives of large private enterprises on the one side and the scientists of the JRC on the other side. Of course, both of these groups of actors were embedded in the wider expertise discourse on H & FC and the expertise developed by them was also influenced by their discussions with further actors. However, based on the resources available to them, both the large private enterprises and the scientists of the JRC play a more important role in the establishment of the expertise produced in the expert groups of the EC than others actors as will be outlined under the next two subheadings. First, however, how the large private enterprises and the scientists of the JRC produced the expertise outlining a complementary relationship between the different drivetrain technologies and fuels.

The large private enterprises such as car manufacturers, oil and gas companies, energy utilities, and industrial gas companies outlined their view on the future prospects of H & FC vehicles, battery electric vehicles, and plug-in hybrids in the so-called McKinsey report (McKinsey 2010). While the consultancy McKinsey provided analytical support to the study and also smaller companies and non-governmental organizations were involved in its conduct, it was mainly the large private enterprises who led the development of the McKinsey report. Altogether the report can be seen as the collective agreement of these different actors on the future potential of fuel cell, battery, and plug-in vehicles which provided the actors involved with a common frame of reference and with shared expertise that they could use in the discussions with further actors. In fact, the influence of the McKinsey report cannot be underestimated as it was used as a source of expertise in different expert groups of the EC and in the Impact Assessment on the continuation of a modified FCH JU in Horizon 2020.

The McKinsey report defines three different types of electric vehicles which are fuel cell electric vehicles, battery electric vehicles, and plug-in hybrids and compares these with conventional vehicles powered by an internal combustion engine in terms of economics, sustainability, and performance (McKinsey 2010, 2, 3). In the study only light duty vehicles were considered that is to say passenger cars, while medium or heavy duty vehicles were not included. The results of the study were developed by a combined forecasting and backcasting approach relying on confidential and proprietary data from the industrial actors involved. Based on these data, projections for the development of the different technologies were made until 2020 and beyond 2020 assumptions on learning curves and annual improvement rates were taken into account to estimate the development until 2050. Based on the estimated conditions prevailing in 2050, the development pathways needed to achieve a specific market penetration by the different powertrain technologies by 2050 were backcasted until 2010 (McKinsey 2010, 18).

The main message of the report is that all three different types of alternative drivetrains bear the potential to contribute to an emission-free transport system and that all of them serve different segments of the car market. Therefore, it is to be most likely that all three different drivetrains are to play a complementary role in the future transport system. While battery electric vehicles are to be best suited for smaller cars and short trips, fuel cell vehicles are to constitute the lowest carbon solution for medium-sized and larger cars used for longer trips. Plug-in hybrids are to be a good solution for short trips or for regions in which sustainably produced biofuels are available. Hence, if the EU wants to achieve its $CO_2$ reduction objectives by 2050, all three types of alternative drivetrains will be needed and should be developed in common (McKinsey 2010, 4-8).

The report also includes economic assumptions on the development of the three alternative drivetrains in the future which are to be cost competitive to vehicles powered by internal combustion engines by 2025 in terms of the total costs of ownership over the entire lifetime of the vehicle. This development is to be enabled by an expected decrease in the cost of fuel cell systems by 90% and a decrease in the component costs of battery electric vehicles by 80% until 2020 due to economies of scale and incremental improvements in technology. Plug-in hybrid vehicles are to be more economic than battery and fuel cell vehicles in the near term future but their costs are to converge after 2030 (McKinsey 2010, 5).

All of three different types of alternative drivetrains can, of course, only be deployed if the appropriate infrastructure for refuelling and recharging is in place. It is expected that the cost of hydrogen will be reduced by 70% by 2025 due to a higher utilization of the refuelling infrastructure and economies of scale. The costs for the built-up of the different infrastructures required for the different drivetrains are to be very similar to each other. While the costs of a hydrogen infrastructure are estimated to be around € 1000-2000 per vehicle, the current costs for an electric charging infrastructure are to range from € 1500-2500 per vehicle (McKinsey 2010, 5, 8).

In fact, the missing infrastructure is portrayed as the main problem preventing H & FC from commercialization as the vehicles themselves are supposed to have reached technical maturity. It is stated that the technological hurdles such as, for example, hydrogen storage or the efficiency and durability of fuel cells have been solved. Therefore, the focus in the development of fuel cell vehicles has shifted from demonstration to commercial deployment. Mass production and economies of scale are to further reduce the costs of fuel cell vehicles and thus car manufacturers have announced their ambition to commercialize fuel cell vehicles by 2015 (McKinsey 2010, 13). The only thing missing is the required infrastructure and for this reason a coordinated roll-out plan for the infrastructure required for fuel cell electric vehicles, battery electric vehicles, and plug-in hybrids is demanded (McKinsey 2010, 53).

Thus the common view and the shared expertise that the different actors involved have agreed upon in the compilation of the report can be summed up as following. All three drivetrains will be needed to achieve the EU's emission reduction objectives by 2050 and should thus be developed in common. Furthermore, they do not compete with each other but rather will serve the needs of different segments of the car market. Finally, the three drivetrains are technically mature but the missing infrastructure prevents a wider commercialization. However, the car manufacturers are committed to begin the mass production of fuel cell vehicles by 2015 if the required infrastructure is in place.

This expertise developed in the McKinsey report was to be further validated and stabilized in the years to come. In fact, the McKinsey report has been used for the Technology Maps of the JRC, the Financial and technology outlook on the European H & FC sector 2014-2020 of the NEW IG, the Impact Assessment for the FCH 2 JU, the two reports of the Expert Groups on Future Transport Fuels, and the EC Communication "Clean Power for Transport" in 2013 as will be illustrated in the further parts of this chapter. First, however, the following paragraphs will outline how further expertise supporting the view of a complementary relationship between H & FC vehicles and battery electric vehicles was developed by another important actor in the expertise discourse on H & FC which is the scientists of the different institutes of the JRC of the EC.

In fact, after the launch of the FCH JU the JRC first had to define its new role in the development of H & FC in relation to the FCH JU. Before the launch of the FCH JU, all EU H & FC projects including those of the JRC have been funded under the different schemes of the FPs. Thereafter, however, the FCH JU is equipped with its own budget deciding upon the largest part of the funding available for H & FC from the European Community in the area of R&I policy[10], while the JRC still receives its own budget from the FPs to conduct its H & FC projects. Thus the scientists of the JRC had to define their new role in relation to the FCH JU so that research in the area of H & FC is not duplicated but rather conducted in a supplementary way by both organizations. Eventually, the different units and institutes of the JRC involved in the area of H & FC mostly deal with pre-normative research which refers above all to the development of viable testing methodologies and approaches so that for instance the quality of hydrogen that is to say its purity can be appropriately measured. In this way the research conducted by the JRC is to contribute to the development of international codes, standards, and regulations which are needed to support the global development and commercialization of H & FC and to ensure common standards and a specific quality.

In addition to their research activities on H & FC, the scientists of the JRC have also been one of the most important actors in the development of expertise on the future prospects of H & FC and in promoting this expertise in various expert groups. The CONCAWE/EUCAR/JRC studies, for example, that have been explained in detail in subchapter 7.2.3, constitute one of the JRC's activities in estimating the future prospects of H & FC. The scientists of the JRC have also developed specific expertise demarcating a

10 Of course, research and development activities can, in principle, also be funded through the Structural Funds and the Cohesion Funds of the EU if the conditions required are fulfilled.

specific role for H & FC in a future emission-free transport system against related technologies such as batteries. Several scientists of the Institute for Energy of the JRC have together with researchers from the European Space Agency published an article in the scientific journal "Acta Astronautica" in which they examine the potential synergies between H & FC applications in the terrestrial and in the aerospace sector. In the article the authors plot the achievable range of fuel cell and battery electric vehicles against the weight of the vehicle in question:

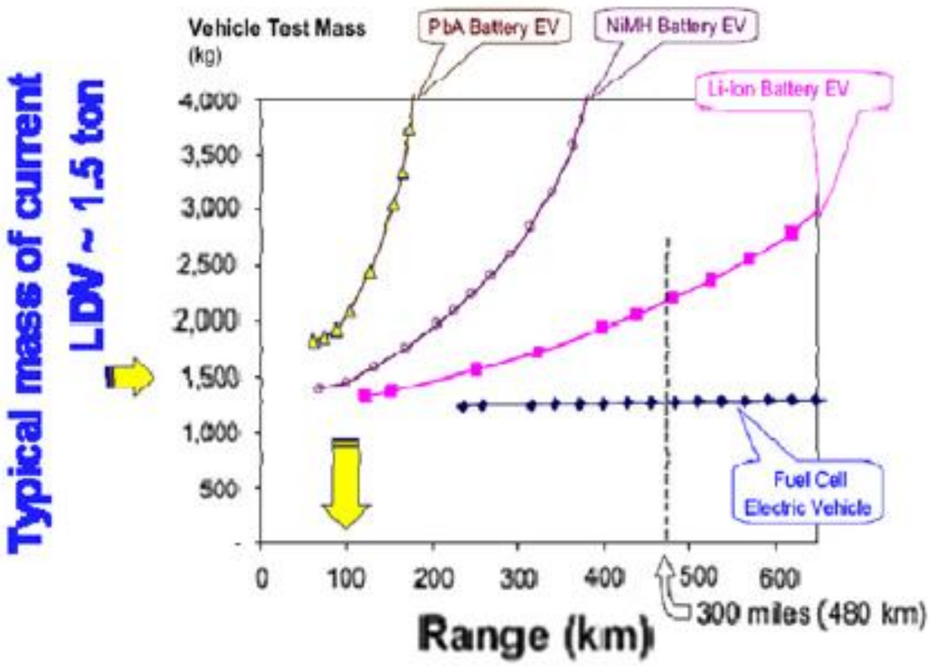



**Figure 16**, Range of vehicles with different drivetrains plotted against the weight of the vehicle

Source: (Frischauf et al. 2013, 22)

As can be seen in the figure above, the main message is that fuel cell vehicles are best suited for higher ranges of 400 km and more because the weight of the batteries that would be required to achieve these ranges rises steeply. Hence the higher power and energy density provided by fuel cell vehicles powered by hydrogen speaks for applying these for vehicles that aim at achieving ranges of more than 400 km. For ranges below 400 km, however, the battery electric vehicle is best suited for (Frischauf et al. 2013, 22). Thus the expertise developed confirms the view of a complementary relationship in which battery and fuel cell vehicles supplement each other as they serve different segments of the car market.

Simultaneously, the article shows that the scientists of the JRC are among the few actors that continued to speak of the hydrogen economy which was promoted by the decision-makers of the EC in the first years of the new millennium (Frischauf et al. 2013, 9, 10). The scientists of the JRC elaborate the chances of future technological spin-off effects that might lead to a deployment of H & FC applications from the transport sector in the aerospace sector. Their conclusion is that a deployment of H & FC applications in the aerospace sector is likely to come in the future due to the high power and energy density of H & FC applications which make them more suitable than related technologies (Frischauf et al. 2013, 23, 24).

In sum, the paragraphs above have explained how different supporters of H & FC have developed the expertise outlining a complementary relationship between different drivetrain technologies and fuels in a future emission-free transport system. The different drivetrain technologies and fuels are to serve different segments of the car market based on their different technical proprieties. H & FC are to power larger passenger cars that cover longer driving ranges, while battery electric vehicles are to be used in urban settings to cover shorter distances. Subsequently, it will be illustrated under the following subheading how the different supporters of H & FC established this view of a complementary relationship between the different drivetrain technologies and fuels in the different expert authorities of the EC.

*Establishing the expertise on H & FC in the different expert authorities of the EC*

The following paragraphs describe how the different supporters of H & FC established their expertise outlining a complementary relationship between the different drivetrain technologies and fuels in the different expert authorities of the EC such as the Strategic Energy Technologies Information System and the Expert Group on Future Transport Fuels. The large private enterprises involved in the development of H & FC and the scientists of the JRC who were supportive of H & FC were the most important actors promoting a complementary relationship between the different drivetrain technologies and fuels in the different expert authorities. In addition, the large private enterprises and the scientists of the JRC were supported by those officials of the EC who wanted to keep H & FC on the European agenda.

Indeed, establishing the view of H & FC as fulfilling a specific role in a future emission-free transport system in the expert authorities of the EC was an important issue as these constitute a key source of expertise for the decision-makers of the EC. Therefore, the following paragraphs will first outline how H & FC were established as promising technologies of the future in the Strategic Energy Technologies Information System of the EC before it is explained how the view of a complementary relationship between the different drivetrain technologies and fuels was established in the reports of the Expert Group on Future Transport Fuels.

The Strategic Energy Technologies Information System (hereinafter SETIS) was set up by the EC in order to establish an open-access information system on energy technologies which is to foster the exchange of information and data among the actors involved in the development of the technologies required to achieve the EU's climate and energy policy objectives. SETIS is managed and implemented by the JRC which has set up a central website to provide all the information gathered and the expertise developed to all the actors involved in the implementation of the Strategic Energy Technology Plan of the EC (Joint Research Centre 2014c).

Hence SETIS is to constitute a central tool in the governance of the SET-Plan illustrating the progress and future potential of new energy technologies to the private and public organizations involved in their development. For this purpose, the JRC publishes reports outlining not only the technical progress of specific energy technologies but also the private and public investments into these, the research conducted on the materials needed for specific energy technologies, and the education and training activities performed to develop the workforce needed to take care of the new technologies in the future. One of these reports is the Technology Map of which an updated version is published every two years. The Technology Maps did not only constitute a key source of information for the Impact Assessment on the launch of the FCH 2 JU but also provide a prime example of how the JRC develops expertise on H & FC. Therefore, the following paragraphs are dedicated to explaining how the progress and the future potential of specific energy technologies are assessed in the Technology Maps of the JRC.

To increase the validity of the assessments the scientists of the JRC consider many different sources of expertise for the Technology Maps. The Technology Map 2011, for example, was, among others, based on information on H & FC from the US Department of Energy, on the results from Japanese and Korean H & FC programmes, and on reports of consultant companies such as McKinsey and Navigant Research (Joint Research Centre 2011, 132). In case of contradictory information the scientists of the JRC apply their own bases of evidence and scientific tools to identify what information are supported by the wider scientific literature. Furthermore, the scientists talk to their non-European colleagues to collect further opinions on the matter in question. The concrete numbers outlining the performance characteristics of light duty fuel cell vehicles rely for instance on the results of H & FC demonstration projects carried out in the EU, in Japan, in South Korea, and in the USA (Joint Research Centre 2011, 117).

The Technology Map 2011 describes H & FC as technologies that will only play a minor role in the achievement of the EU energy policy objectives for 2020 due to their stage in development. While some H & FC applications already are available on the market, the bulk of H & FC technologies is expected to become commercialized in the near term future due to the large improvements that have been achieved in the demonstration projects carried out in the past years. Therefore, the Technology Map describes H & FC as bearing a huge potential to contribute the long-term decarbonization of the European energy system by 2050 (Joint Research Centre 2011, 116).

In addition to the Technology Maps of the JRC, two reports of the Expert Group on Future Transport Fuels constituted another important source of expertise for the decision-makers in the EC. The EC set up an Expert Group on Future Transport Fuels in March 2010 with the task to identify the most promising alternative fuels for the replacement of fossil fuels in the transport system in order to achieve the desired decarbonization (European Expert Group on Future Transport Fuels 2011a, 7). The Expert Group was composed of a wide range of different member organizations related to the transport sector such as European associations as ACEA, ERTRAC, EUCAR, EURELECTRIC, or UITP, and civil society organizations such as Transport & Energy or Greenpeace. The EC was represented by 10 different DGs of which DG MOVE was the most important one as it was in charge of the development of the reports of the Expert Group. Furthermore, the JRC was represented in the Expert Group by several scientists and the European Environmental Agency, too (European Expert Group on Future Transport Fuels 2011a, 7).

The Expert Group has published the two reports “Future Transport Fuels” and “Infrastructure for Alternative Fuels” in 2011 (European Expert Group on Future Transport Fuels 2011a, 2011b). Both reports describe H & FC and batteries as the most promising options to establish a future emission-free transport system with both technologies serving different segments of the car market. While battery electric vehicles are to be best suited for small passenger cars and short ranges, fuel cells are more viable for large passenger cars and longer ranges (European Expert Group on Future Transport Fuels 2011a, 14, 18, 38, 2011b, 8). Therefore, the general tenor of the reports was that there will not be one single solution for all different purposes in the transport sector but rather that different solutions will be needed so that different fuels and drivetrain technologies should be developed in parallel.

Hence both reports exemplify how the different supporters of H & FC succeeded in establishing their view of a complementary relationship between the different drivetrain technologies and fuels in the expert authorities of the EC. Some of the main references of the Expert Group report came from the EUCAR/CONCAWE/JRC studies and the McKinsey report. The comparison of the energy efficiencies and the GHG emissions of the different fuels considered are for instance based on the analyses from the EUCAR/CONCAWE/JRC studies (European Expert Group on Future Transport Fuels 2011a, 43-45). In addition, the McKinsey report is referred to when stating that the cost of fuel cells could be reduced by 90% by 2020 and that the costs for the built-up of the infrastructure needed for hydrogen are comparable to those of the infrastructure required for battery electric vehicles (European Expert Group on Future Transport Fuels 2011a, 17, 2011b, 7, 8).

Thus the two reports of the Expert Group provide prime examples of how specific expertise on H & FC is established and stabilized in the expert authorities of the EC. The large private enterprises that compiled the McKinsey report succeeded for instance in establishing it as one of the key sources of expertise used in the Expert Group on Future Transport Fuels. In addition, the complementary view on the different drivetrain technologies and fuels was also promoted by the officials of the EC and the scientists of the JRC who were supportive of H & FC and who wanted to keep these technologies on the European agenda. Subsequently, the next subchapter will illustrate how the specific expertise on H & FC developed was used to legitimize the continuation of the FCH JU by highlighting the importance of H & FC for the achievement of the broader objectives EU competitiveness, energy, and transport policy.

### 9.2.3 Situating H & FC in Horizon 2020 in order to legitimize the continuation of the FCH JU

This subchapter describes how the supporters of H & FC situated these technologies in Horizon 2020 in order to legitimize the continuation of the FCH JU. For this purpose, H & FC were portrayed as key means to achieve the broader objectives of EU innovation, energy, and transport policy. First, it is explained how the supporters of H & FC illustrated that these technologies will contribute to innovation in the EU and increase the competitiveness of the European industry. Second, it is outlined how H & FC were portrayed as important means for energy storage and linked to the development of renewable energy sources which is one of the key priorities of European energy policy. Finally, it is explained how the importance of H & FC for the achievement of the objectives of European transport policy was outlined by highlighting the specific role of these technologies in the establishment of a future emission-free transport system.

*European innovation and competitiveness: H & FC are approaching the market*

Innovation and competitiveness have constituted two of the key aspects of the Lisbon Strategy of the first decade of the new millennium and they continued to be two of the main components of the Europe 2020 agenda for the second decade. Consequently, the supporters of H & FC emphasized the future potential of these technologies for preserving jobs and stimulating economic growth and referred to the national H & FC programmes in Japan, in South Korea, and in the USA in order to underline that the EU has to compete with these countries if it wants to achieve the economic potential of H & FC.

Indeed, one of the most important arguments of the supporters of H & FC was that these technologies are closer to commercialization than ever before and that there will be products available on the market very soon. To underline this argument the proponents of H & FC emphasized that niche markets have developed in recent years so that the H & FC sector is selling its first products which are generating revenue. It is argued that these niche markets are a stepping stone for mass production and commercialization of other H & FC products as the following quotation of an official of the EC illustrates:

> "It is a nascent technology so it was mainly focused on research and development until recently. Now it starts to have a small business, I mean the private sector is

> starting to sell some products. Instead of investing in R&D and getting public support to develop the technology, now they are starting to have some incomes from their selling. So we are trying to assess how this will progress in the future to see if this technology is the future, for now it is a just bit of niche markets like forklifts in the US or residential fuel cell heat and power in Asia, in Japan in particular, or for back-up power for telecom. So you have a few niche markets which have developed in the last few years and now for the future we are looking at big applications like transport, cars, mass production." (Interviewee 11, 2013)

The main message is that H & FC are very close to commercialization and only a few more things have be sorted out before fuel cell vehicles powered by hydrogen are manufactured and sold in large amounts. Some of the reasons why there are just a few hundred fuel cell vehicles on the streets yet, are for instance that costs of fuel cell systems have to be further reduced, supply chains for spare parts etc. have to be further optimized, the specific level of purity of the hydrogen needed still has to be determined, and more tests and demonstration projects in different environments and under varying conditions have to be conducted. However, the supporters of H & FC argued that these are comparably minor issues that will be solved in the next two or three years so that the large car manufacturers will begin with mass production in 2015 or 2016 and more H & FC vehicles will be seen on the street soon.

The argument of H & FC approaching the market was also linked to the broader policy discourse on the competition of the EU with countries such as China, Japan, South Korea, and the USA. The supporters of H & FC argued that the EU is competing with these countries in bringing H & FC vehicles to the market first so that jobs in the vehicle manufacturing sector can be preserved in the EU. Hence it was not argued that H & FC will create many new jobs in the EU but rather that action is needed in order to preserve the existing jobs because the market will shift from cars that run on diesel and gasoline to other fuels and drivetrains so that if these new cars are not produced in the EU then they will be produced somewhere else. The following quotation of an official of the EC exemplifies this line of thinking:

> "If we continue on diesel, petrol etc. and all the other continents, the Americans, the Japanese, the Koreans, they develop Zero-Emission-Technologies, there will be a moment when they will sell everything and we will have lost our industries. So we need to prepare for a transition in the transport sector. So we will not create jobs because we will produce many cars, maybe less, you see how the sector is doing now, it is a bit difficult, but at least we will preserve jobs, these manufacturing jobs in Europe." (Interviewee 11, 2013)

The supporters of H & FC also linked these technologies to the EC's understanding of competition with other countries for economic growth, technological leadership, and jobs in specific industrial sectors. Japan and the USA were portrayed as leading the global development of H & FC with the EU lagging behind and countries such as China and South Korea rapidly catching up. To underline this argument the supporters of H & FC referred to the national H & FC programmes of these countries illustrating the investments that have already been made, those that are planned for the next years, and the objectives that are to be achieved. In the financial and technology outlook on the European H & FC sector for 2014-2020 of the NEW IG it was for instance outlined that the US Department of Energy has invested $ 170 million in the development of H & FC in 2010 and 2011 and that it is estimated in Japan that the H & FC market is to grow up to $ 3.9 billion in 2012, while South Korea attempts to create 560,000 jobs in the H & FC sector by 2025 (NEW Industry Grouping 2011b, 19, 20). These numbers were used to underline that the EU will not achieve technological leadership in H & FC if it does not take up the competition with these countries and increases its efforts in the development of H & FC.

*European energy policy: Linking H & FC to the development of renewable energies*

The overall strategy of Europe 2020 constituted the new dominant frame of reference into which other EU policy fields such as energy and transport had to be embedded. In 2010 for instance the EC published its Communication "Energy 2020. A strategy for competitive, sustainable and secure energy" in which it not only confirms the 20/20/20 objectives[11] but also outlines the five new top priorities of EU energy policy: 1) Achieving an energy efficient Europe, 2) Building a truly pan-European integrated energy market, 3) Empowering consumers and achieving the highest level of safety and security, 4) Extending Europe's leadership in energy technology and innovation, 5) Strengthening the external dimension of the EU energy market (European Commission 2010b, 5, 6). Hydrogen is part of the fourth priority as an innovative storage technology for electricity generated from renewable energies (European Commission 2010b, 16).

In fact, the supporters of H & FC highlighted the importance of these technologies for the achievement of the objectives of European energy policy in two ways. First, it was argued that hydrogen will constitute an important means of energy storage in the future. Second, it was tried to link hydrogen to renewable energies as it is one of the main objectives of EU energy policy to increase the share of renewable energies in the overall energy consumption and electricity generation. Indeed, both arguments were also closely linked to each other as will be illustrated in more detail in the following paragraphs.

The main point was that in the future large capacities to store energy will be needed due to the intermittent nature of renewable energies. This means basically that electricity generation from renewable energies does not necessarily match the electricity demand of the consumers. For instance, there are periods with heavy winds and times where the wind does not blow at all. Also the sun can shine through the cloudless sky several weeks in a row but might as well disappear behind thick clouds on many consecutive days. Thus in some periods of time a high amount of electricity can be generated from renewable energies, while in other times the capacities are rather low or close to zero.

11 The 20/20/20 objectives refer to a reduction of GHG emissions by 20% compared to the level of 1990, to an increase of the share of renewable energy sources in the overall energy consumption to 20%, and to a 20% improvement in energy efficiency. All of these objectives are to be achieved by 2020 (European Commission 2010b, 2).

However, the electricity demand of the consumers does not necessarily develop along the same lines as electricity production from renewable energies. Therefore, in times of a surplus of renewable energies, means of energy storage will be needed so that no electricity is produced and fed into the grid that will be wasted in the end as there is no demand for it at that particular moment. Instead, it was argued that the surplus of renewable energies should be stored by appropriate means so that it can be used for electricity generation at times when the capacity for electricity generation from renewable energies is below the electricity demand of the consumers. Thus, means of energy storage will be required to match the gap between electricity demand and supply in the future.

Based on this line of thought the supporters of H & FC argued that hydrogen constitutes the ideal means of energy storage in times of a surplus of electricity generated from renewable energy sources. This surplus of electricity could be used to generate hydrogen which could then either be used to power fuel cell vehicles or it could be stored and converted back to electricity in times of a high electricity demand. Consequently, hydrogen was not only to allow balancing the intermittent nature of renewable energies but also to constitute a means of introducing these into the transport system and to break the dependency on oil-based fuels.

In addition, hydrogen was also portrayed as superior to other technologies for the purpose of energy storage. The battery technology for instance which could also be used to store electricity was argued to be too expensive if used for electricity storage only. Rather, it was argued that chemical means of storage would be the only viable ones if large amounts of energy are to be stored over several days and that among the different chemical means of storage hydrogen was the most suitable one. The following quotation of a scientist of the JRC exemplifies this line of argument:

> „Hydrogen as an energy carrier will play a much more important role in the future energy system and in the transition to a low-carbon economy than now to allow the increased uptake of renewable in the electricity grid by including high energy density,

long duration storage. So there are different requirements for a higher share of renewable in the electricity grid, remove the congestion, strengthen the grid itself, try to influence the demand by matching it, so demand management to the generation, and the fourth, technology solution definitely is to have higher storage capabilities and there emphasis is on hydrogen and expectations for hydrogen are very high and this is what we are discussing there. In the storage area, there is hardly any discussion on the relative dominance of hydrogen because if you consider the amounts of storage which will be needed in the European energy grid, it is only hydrogen that can ultimately meet these demands." (Interviewee 9, 2013)

In sum, it was argued that hydrogen allows for a completely carbon-free energy cycle and provides the opportunity to store the electricity generated from renewable energy sources in virtually unlimited amounts (NEW Industry Grouping 2011b, 14-16). Hence H & FC could contribute to balancing the intermittent nature of renewable energies which were to constitute an increasing share in the overall energy consumption and electricity generation in the future. The hydrogen generated from renewable energies could for instance be used in fuel cells to produce electricity in locations which are not connected to the electricity grid such as mines, telecom stations, or road-side and rail-side signage. In addition, fuel cells were portrayed as devices that can generate electricity for a wide variety of applications ranging from small, portable devices to vehicles and combined heat and power systems in private households and industrial buildings (NEW Industry Grouping 2011b, 16).

*European transport policy: H & FC for an emission-free transport system*

The supporters of H & FC highlighted the importance of these technologies for the achievement of the objectives of EU transport policy by outlining the specific role of H & FC in a future emission-free transport system. H & FC vehicles, battery electric vehicles, and plug-in hybrids were portrayed as complementary technologies that will serve different segments of the car market and thus fulfil different roles in the development of zero-emission vehicles. In order to underline this point of view the supporters of H & FC applied the expertise produced in the different studies and expert reports outlined in subchapter 9.2.2 to highlight the strengths and weaknesses of the different drivetrain technologies and fuels.

Battery electric vehicles for instance were to be very energy efficient but it was argued that they would only allow for short driving ranges. Furthermore, the time required for recharging the batteries was to be rather long and batteries were to be rather expensive. Also Biofuels could be used to reduce the emissions of the transport sector but their production was to require large areas of agricultural space so that they often would compete for space with the production of food. The supporters of H & FC acknowledged that these technologies were still very expensive, too, and there still was no hydrogen refuelling infrastructure in place but on the plus side H & FC vehicles would allow for long driving ranges and the production of hydrogen would not compete with the production of food. Consequently, an official of the EC stated: “There is no champion today, there is not one technology that will solve all problems unless someone is able to demonstrate that and I am not sure there is” (Interviewee 11, 2013).

Furthermore, it was argued that each of the different drivetrain technologies and fuels targets different segments of the car market because of their different strengths and weaknesses. Battery electric vehicles, for example, might be best suited for small cars and the use in an urban environment which would be characterized by short trips inside of a city. Hence they might constitute the ideal solution for the second car of a family. H & FC vehicles, however, were to allow for much longer trips and bigger cars so that they would be better suited for people who regularly need to drive long distances or to transport goods. The main point was that the different technologies serve different segments of the car market so that they rather supplement than exclude each other.

Thus, due to the different strengths and weaknesses of each technology and the different segments of the car market that they potentially target, the supporters of H & FC argued that there is no need to choose a winner yet, but rather that all technologies should be developed in common so that the market could decide in the future what the preferred solution will be. The main argument was that it is too early to make a decision for one of the technologies and to stop research on the other ones. Therefore, it was argued that batteries and H & FC should be developed in parallel and that the decision on what technology will be a better solution in the end should be taken at a later stage in the development. This line of argument is well illustrated by the following quotation of an official of the national German administration:

> "I am always saying, let both develop in parallel, the technological development and the market will make the decision in the end. We need both alternatives. It is very important that both are developed in the current situation. Maybe in ten years we will be able to take a decision that could be possible." (Interviewee 7, 2011)

In sum, the supporters of H & FC argued that these technologies could contribute to the achievement of the objectives of EU transport policy as fuel cell vehicles powered by hydrogen have no tail-pipe emissions and can contribute to the achievement of an emission-free transport system. Furthermore, H & FC vehicles were not to compete with the battery electric vehicles or plug-in hybrids as all three different drivetrain technologies and fuels would serve different segments of the car market. H & FC were to be best suited for heavy cars and long distances due to economic and technical advantages over battery electric vehicles and plug-in hybrids.

## 9.3 The policy discourse: Justifying the continuation of a modified FCH JU in Horizon 2020

This subchapter explains the policy discourse on H & FC that resulted in the launch of the FCH 2 JU in Horizon 2020. The Council of the EU has officially established the FCH 2 JU by a regulation on 6 May 2014 (Council of the European Union 2014). As required by the legal regulations on the launch of a Joint Technology Initiative, the launch of the FCH 2 JU was preceded by an Impact Assessment in which it had to be demonstrated that the continuation of a modified FCH JU is the most suitable policy option for the promotion of H & FC in Horizon 2020 (European Commission 2013a). The modified FCH 2 JU of Horizon will have a different formal governance structure and apply different legal regulations for its operation than the previous FCH JU of FP 7. However, while the negotiations of the continuation of the FCH JU and the conduct of the accompanying Impact Assessment had just been finished while the data collection for this thesis was completed by early 2014, the discussions between the EC, the EP, and the Council of the EU on the legal set-up of the FCH 2 JU had not been finished, yet. Therefore, this subchapter cannot clarify how the modified formal governance structure of the FCH 2 JU came into being but will rather focus on explaining how the continuation of a modified FCH JU in Horizon 2020 was justified in the policy discourse on H & FC.

The key role in the justification of the continuation of a modified FCH JU in Horizon 2020 was played by specific policy entrepreneurs who have already dominated the production of expertise on H & FC. These high-ranking officials of the EC and the representatives of large private enterprises transferred the expertise produced into the policy discourse and used it to advocate the continuation of the FCH JU to the decision-makers in the EC. Due to their own hierarchical position in the EC and their resources such as time and financial means, these actors had a better access to the decision-makers in the EC than the other promoters of H & FC such as scientist of public research institutes and representatives of smaller companies. The high-ranking officials of the EC and the representatives of large private enterprises used their direct access to the decision-makers in the EC to advocate the future potential of H & FC to contribute to the achievement of the objectives of EU innovation, energy, and transport policy in order to legitimize the continuation of the FCH JU in Horizon 2020.

The following subchapter will describe the policy discourse on H & FC in more detail. First, it will be illustrated how the supporters of H & FC gathered further support for the continuation of the FCH JU in the EC and in the EP. Second, the discourse coalition that was sceptical of H & FC and that doubted the future potential of these technologies will be described. Third, it is highlighted how the discourse coalition for the continuation of the FCH JU used the expertise developed to resolve the critique of H & FC. Fourth, it will be explained how the expertise developed was used in order to demonstrate in the Impact Assessment that the continuation of a modified FCH JU is the best policy option available for the promotion of H & FC in Horizon 2020. Finally, subchapter 9.3.5 summarizes the policy output of the policy discourse on H & FC which resulted in the establishment of the FCH 2 JU by the Council of the EU on May 2014.

### 9.3.1 The discourse coalition for the continuation of the FCH JU

The discourse coalition for the continuation of the FCH JU comprised officials from all different hierarchical levels of the EC, scientists of the JRC, representatives of private enterprises and scientists of public research institutes and universities. Most influential in promoting the continuation of the FCH JU, however, were high-ranking officials of the EC and the representatives of large private enterprises as these possessed the necessary resources that granted them direct access to the decision-makers in the EC. This allowed these policy entrepreneurs to transfer the expertise produced into the policy discourse and to use it to advocate the future potential of H & FC for the achievement of the objectives in EU innovation, energy, and transport policy to the decision-makers in the EC. In this way, the policy entrepreneurs played a key role in legitimizing the continuation of the FCH JU by linking the two discourses on policy and expertise to each other.

The following paragraphs are to illustrate in more detail how the different supporters of H & FC promoted the continuation of the FCH JU in the policy discourse. First, it is illustrated how the continuation of the FCH JU in Horizon 2020was advocated to the decision-makers in the EC. Thereafter, it is outlined how the different supporters of H & FC gathered further support for the continuation of the FCH JU and for keeping H & FC on the European agenda.

*Advocating the continuation of the FCH JU in Horizon 2020 to the decision-makers in the EC*

To understand how the continuation of the FCH JU in Horizon 2020 has been promoted and defended against critique it is important to take into account the internal hierarchy and organization of the EC. Taken together the analysis of the interviews conducted for this thesis suggests that, while many different DGs participated in the discussions on the continuation of the FCH JU, most of the promoters of H & FC came from DG R&I, DG ENER, and DG MOVE. As confirmed by several officials of the EC and scientists of the JRC for instance H & FC had their supporters on all hierarchical levels of these DGs such as Head of Unit, Director, and Deputy Director-General etc (Interviewee 4, 2011; Interviewee 9, 2013; Interviewee 11, 2013). These supporters advocated the specific importance of H & FC for the achievement of the objectives in EU innovation, energy, and transport policy to their colleagues in their own and in other Units, Directorates, and Directorate-Generals of the EC in order to justify the continuation of the FCH JU in Horizon 2020.

Of course, also the then Commissioner for Transport, Sim Kallas, the then Commissioner for Research, Marie Geoghegan-Quinn, and the then Commissioner for Energy, Günther Oettinger, were involved in these discussions. However, these Commissioners were less actual promoters of H & FC but rather those who finally approved the role of H & FC in Horizon 2020. The Commissioners are the ones who have the final say on whether H & FC fit into the broader policy objectives of the EC or not. Thus the supporters of H & FC advocated the future potential of these technologies to the Commissioners in order to legitimize the continuation of the FCH JU. The following quotation of a scientist of the JRC illustrates quite well these internal dynamics in the EC showing that the three Commissioners themselves might not be active promoters of specific technologies but rather that they are open to being demonstrated that specific technologies will be needed to achieve certain policy objectives:

> "From within the EC, Maire Geoghedan-Quinn is not against hydrogen and fuel cells because if she were against, I guess this group would have been met with much more resistance in their work." (Interviewee 9, 2013)

The decision-makers in the EC were the ones that eventually had to approve the role of H & FC in Horizon 2020 put forward by the supporters of H & FC. Hence the decision-makers of the EC were the ones who finally stabilized the expertise developed and the storyline uttered by the supporters of H & FC before the proposal of the EC on the launch of the FCH 2 JU was put forward to the EP and the Council of the EU. The following quotation of an official of the EC illustrates very well the interplay of the different hierarchical levels of the EC in the stabilization of a specific storyline and the expertise it is based on:

> "But in the recent past the Cabinets of the two Commissioners, Oettinger for Energy, and Georghegan-Quinn for Research, they have been quite active because now we are preparing the continuation of the FCH JU. The European Commission will propose the continuation so the Cabinets of the Commissioners are getting quite involved because they want us to justify why we are proposing that for good reasons. They want to see whether they agree and until now they agree. They want us to build a very solid case for them to go to the Parliament and the Council to defend the prolongation." (Interviewee 11, 2013)

A further actor promoting H & FC inside of the EC are those scientists of the Joint Research Centre who are supportive of H & FC. The scientists of the JRC were consulted regularly both formally and informally by their policy-making colleagues in the other DGs of the EC and thus they had an influence on the discussions inside of the EC, too. They have for instance been formally consulted for the Impact Assessment on the launch of the FCH 2 JU. More often, however, they had informal talks to their policy-making colleagues in the different DGs of the EC in which they expressed their view on H & FC and in which they attempted to resolve critique and scepticism on H & FC.

Apart from the formal hierarchical structures and the political and technical discussions, also personal relations and internal power struggles played a certain role in the discussions on the continuation of the FCH JU in Horizon 2020. Individual policy officers of the EC might for instance on the basis of personal relations not be invited to the discussions on a specific issue although their work actually is related to that issue. These personal relations can rely on a lot of things such as people just having very different world views in general without regard to the specific issue in question. It could also be that a specific person has just recently entered the EC or has been transferred from one DG to another one so that he or she just has not established him- or herself in the personal hierarchy of that DG yet.

In addition to the internal discussions of the EC on Horizon 2020, also the representatives of large private companies contacted officials on different hierarchical levels in the EC in order to persuade them of the importance of H & FC for the achievement of the objectives in EU innovation, energy, and transport policy in order to legitimize the continuation of the FCH JU in Horizon 2020. These policy entrepreneurs followed the political discussions and through their personal contacts they knew very well who in the EC is in favour of H & FC and who is rather critical. Through these personal discussions with the policy-makers they also got to know the concrete reasons for the critique of H & FC or the sceptical stance on H & FC so that they understood what kind of new expertise on H & FC would have to be developed to resolve this critique. The following quotation of a representative of a private enterprise provides a good illustration of these dynamics:

> “We all know the official political statements. In the discussions with the policy-makers the efficiency rate is often criticized. Hence it is not the case that everyone screams hurray when it comes to the topic of hydrogen. We will have to provide a lot of more information until that issue is fully understood. Partly, they are supporters of other

> technologies although I do not see a competition; neither in the case of mobility nor in the case of storage." (Interviewee 15, 2012)

The industrial companies, public research institutes and the policy and scientific officers in the EC who are supportive of H & FC also organized public events such as international conferences or workshops together. These events were not only to raise the public awareness of H & FC but also to promote the importance of these technologies for the achievement of the objectives in EU innovation, energy, and transport policy to other officers of the EC who had a rather critical or sceptical stance on H & FC. For this purpose, officers of the EC with a rather critical or sceptical stance on H & FC were invited to these events so that they could speak to all the different actors involved in the development of H & FC who would explain their view on H & FC to them. The following quotation of an official of the EC illustrates for instance how the future importance of H & FC for European energy policy was advocated to the officials of DG ENER:

> "For DG ENER they were interested in the storage of renewable energy which is a big topic now, well, hydro pumping or batteries. Fuel cells or hydrogen, we see later. Now they realize that the technologies made some progress and now they are getting closer to competitiveness. … So we are telling them to look more at H & FC because these technologies are approaching the market and we are also telling them to come and meet the industry, they will tell you, and they have had discussions with the industry and after that, their interest has increased, that is my feeling." (Interviewee 11, 2013)

The quotation above also illustrates how the expertise developed in the expertise discourse on H & FC was transferred to the policy discourse on and used to promote the future potential of H & FC to further officials of the EC. In this specific case it was argued that H & FC have progressed significantly so that they are approaching the market and that hydrogen will be an important medium for the storage of renewable energies in the future. This shows how specific policy entrepreneurs linked the two discourses on policy and expertise to each other by first influencing the production of expertise according to their political objectives in order to then use this expertise in the policy discourse to achieve their political objective of keeping H & FC on the European agenda.

*Gathering further support for H & FC and the continuation of the FCH JU*

In addition to advocating the continuation of the FCH JU in Horizon 2020 to the decision-makers in the EC, the supporters of H & FC also promoted these technologies to the policy and scientific officers of the EC, to the Members of the EP, and to different associations of the European industry. One problem of the supporters of H & FC was for instance that the most active promoters of H & FC in the EC have been those that have contributed to setting the hydrogen economy on the European agenda in the early years of the new century. However, several persons of this group of officials have retired in the years of 2012 and 2013 and even more will do so in the following years. Therefore, it is of increasing importance for the supporters of H & FC to advocate the future potential of H & FC for the achievement of the objectives in EU innovation, energy, and transport policy to the new policy and scientific officers of the EC that replaced the retired ones. In contrast to the first generation of H & FC supporters inside the EC, the new policy and scientific officers did not speak of the hydrogen economy but rather regarded H & FC as one among other new energy technologies that will be needed in the future. This altered view on H & FC is well exemplified by the following quotation of an official of the EC:

> "Basically to me it is the fact that it is or it can be, depending on how it is produced, a zero-emission technology which is what we are looking for in terms of greenhouse gas emissions plus air-quality policy targets which would be fairly equivalent in terms of lets say convenience which is very important for people to chose that technology

> compared to fossil fuels. Why? Because mainly the autonomy is more or less the same or can be the same as fossil fuels, more or less 500 km with one tank, and the refuelling time can be comparable, it is a bit longer, but okay, comparable to fossil fuels." (Interviewee 13, 2014)

Apart from the EC, the private and public actors from the NEW IG and the N.ERGHY Research Grouping also try to mobilize support for H & FC in the EP. As during the discussions on the launch of the first JTI for H & FC in the years of 2005-2008, however, H & FC attract only little attention in the EP. There are only three or four Members of the EP who actively promote H & FC such as, for example, Vittorio Prodi from the Group of the Progressive Alliance of Socialists and Democrats or Maria da Graça Carvalho from the Group of the European People's Party. Both were Members of the Committee on Industry, Research and Energy that was in charge of developing the EP's report on the proposal of the EC to set up the FCH 2 JU.

Furthermore, it is noteworthy that new actors from a sector that has traditionally been rather critical of H & FC have begun to support the discourse coalition on the continuation of the FCH JU. Small private enterprises developing renewable energy sources, and in particular wind power, for electricity generation have begun to cooperate with large energy utilities in the development of hydrogen as a means for energy storage. This cooperation would have been rather unthinkable in the first years after the turn of the millennium when hydrogen was strongly associated with nuclear energies by the promoters of renewable energy sources.

Hence by promoting hydrogen as a means for energy storage the discourse coalition on the continuation of the FCH JU has succeeded in persuading some of its former opponents from the renewable energy sector to support the development of H & FC. In fact, the argument of energy storage was used to link hydrogen to renewable energy sources in order to finally resolve the critique from environmental NGOs and Green Parties that primarily linked hydrogen to nuclear energy in previous years. The discourse coalition on the continuation of the FCH JU argued that if the share of renewable energies in electricity generation is to be increased, then hydrogen will be needed to balance the intermittent nature of renewable energy sources. Indeed, the more recent involvement of small renewable energy companies in the development of hydrogen as a means for energy storage increases the weight of this argument. Hence the promotion of hydrogen as a means for energy storage has broadened the discourse coalition on the continuation of the FCH JU.

In addition, the representatives of large private enterprises promoted their view on H & FC in European associations related to the energy and transport sector such as for instance EUCAR or CONCAWE. In fact, after the establishment of the FCH JU was completed in 2011, the representatives of large private enterprises in the FCH JU turned their attention more and more towards the promotion of H & FC and towards advocating the future potential of these technologies to further actors. The following quotation of a representative of a private enterprise in the FCH JU illustrates this ambition:

> "Naturally, we have good contacts to the European Hydrogen Association but there are further energy lobby associations and at the moment we are trying to embed the topic into two issues. Mobility was always dominant due to the vehicle industry, of course, that has said, we need this now and what has now come along is the issue of energy storage in which hydrogen can play a role. Therefore, we currently approach the energy lobby associations, there have always been many activities with the vehicles, also with the vehicle associations EUCAR, CONCAWE and all of these, there were already have had good contacts since the launch of the FCH JU and at the moment we are building up contacts in the direction of energy, too." (Interviewee 15, 2012)

The quotation above also outlines how the policy entrepreneurs used the expertise produced in the expertise discourse on H & FC to gather further support for H & FC in the policy discourse. For this purpose, H & FC were advocated as a promising means of energy storage in the future in order to assure the support of further actors for the development of these technologies.

### 9.3.2 The discourse coalition sceptical of H & FC

The discourse coalition sceptical on H & FC embraced officials in different Directorates of different DGs of the EC that did not concert their actions to prevent the launch of the FCH 2 JU but that shared a rather critical view of H & FC and that uttered this view on their own. This critical view was based on different reasons such as the disappointment of previous supporters of H & FC with the slow progress of the hydrogen economy or the preference of other, related technologies such as the battery technology. Furthermore, some officials had safety concerns and feared that the use of hydrogen is dangerous. Many of these arguments have already been put forward in the debates on H & FC in earlier years which have been outlined in detail in the chapters 6-8. Therefore, the following paragraphs will not reproduce each argument one more time in full detail but rather provide a brief summary of the critique that has been raised on H & FC.

One of the arguments of the critics was for instance that a hydrogen economy has been promised for decades and it still has not come about. The car manufacturers have been promising to start the mass production of fuel cell vehicles for many times but it has never happened. Instead, the start of mass production was only delayed further into the future so that there are still no H & FC products on the market, yet. Therefore, some officials of the EC have been rather sceptical of the chances of seeing any H & FC products on the market in the near or medium term. They did not believe the announcements of the car manufacturers to start the mass production of H & FC vehicles in 2015 and 2016 but rather criticized that such promises have already been made in previous years and have remained unfulfilled.

In addition, there were some officials in the EC who preferred other technologies and above all battery electric vehicles to H & FC. Their main argument was that hydrogen production is inefficient. In fact, hydrogen is only an energy vector and not an energy source so that it has to be produced from primary energy sources first. Electricity generated from wind or solar power has to be used to separate hydrogen from oxygen via electrolysis which, however, includes the loss of a lot of energy as has already been outlined in more detail in the preceding chapters.

Due to these losses of energy in hydrogen production, the opponents of H & FC argued that it would be more efficient to use the electricity generated from renewable energy sources directly instead of inefficiently producing hydrogen with it. In their view battery electric vehicles would be ideally suited for this purpose as batteries can be directly charged with the electricity generated without any intermediate steps and almost without any losses of energy. Thus battery electric vehicles would allow decoupling the transport sector’s dependence on the import of oil and would enable a highly efficient and an emission-free transport system. Therefore, some officials of the EC were sceptical of the potential of H & FC to contribute to the achievement of an emission-free transport system; even when they acknowledged that hydrogen might play a role as a means of energy storage in the future as the following quotation of an official of the EC illustrates:

> “Yes, I face people who are sceptical, not from our DG but from DG ENER I had a person say, well look, I mean hydrogen will not make it as a transport fuel. It has great potential in terms of energy carrier, for example, but transport, yeah, do not really invest too much time into that” (Interviewee 13, 2014)

Finally, some officials in the EC have been concerned about the safety of hydrogen applications. Their point was that hydrogen is highly explosive as was illustrated by the disaster of the Hindenburg airship of 6 May 1937. Although it is still not fully resolved what actually caused the fire of the airship that resulted in the loss 36 lives, many people believe that it was leaking hydrogen that caused the initial ignition. In fact, if gaseous hydrogen and oxygen are mixed together in a certain ratio the result is the highly explosive gas oxyhydrogen. Therefore, some people fear that the use of hydrogen in car tanks could be dangerous; not least during accidents and crashes. This sceptical view of the safety of hydrogen fuelled vehicles is well illustrated in the following quotation of an official of the EC:

> "Yes, there is scepticism on hydrogen and fuel cells and the main scepticism I have heard so far is about the safety aspects of hydrogen because hydrogen still has that perception that it is inflammable, which is true, and therefore when used as a fuel could not be as safe as lets say electricity or fossil fuels and even if it would be safe enough, it would still have issues of public acceptance. … Which is true, I mean public acceptance needs to be worked on, that is for sure, still for many people in the street, when you say hydrogen in a car, they say hoo, explosion. They do not know a lot obviously from a technical point of view, which is normal, but most people associate hydrogen with explosion." (Interviewee 13, 2014)

In sum, the most important arguments of the critics of H & FC were that a commercialization of H & FC has already been promised many times but still has not come about, that the production of hydrogen is inefficient due to high losses of energy, that battery electric vehicles are a more efficient alternative for the achievement of an emission-free transport system, and that there are safety issues with the use of hydrogen as a fuel in vehicles. The following subchapter will illustrate how the supporters of H & FC responded to this critique and attempted to resolve it with specific expertise on H & FC.

### 9.3.3 Resolving the critique of H & FC

This subchapter describes how the supporters of H & FC used their expertise on these technologies to resolve the critique of H & FC. Hence the expertise developed in the expertise discourse on H & FC was transferred into the policy discourse and used to defend H & FC against the critics in order to justify the continuation of the FCH JU in Horizon 2020.

To illustrate this issue in more detail, the subchapter at hand is split into two subheadings. First, it will be outlined how the supporters of H & FC resolved the critique from the supporters of battery electric vehicles by highlighting the specific advantages of H & FC over the battery technology with their specific expertise on H & FC. Thereafter, it will be illustrated how the supporters of H & FC met the scepticism of the commercialization of H & FC and the safety concerns.

*Resolving the critique from the supporters of battery electric vehicles by highlighting the specific advantages of H & FC over the battery technology*

The supporters of H & FC acknowledged that the overall efficiency rate from hydrogen production to its use in a fuel cell vehicle is lower than the efficiency rate for electricity generation and its use in a battery electric vehicle. However, the supporters of H & FC argued that due to the opportunity of deploying hydrogen as a means of energy storage the development of technologies for the production of hydrogen has gained new momentum which will result in considerable improvements in the efficiency of hydrogen production in the next couple of years. The point was that the main technology for hydrogen production, that is to say electrolysis, has been invented a hundred years ago and there have only been little efforts to improve its efficiency in the past decades because there was only a rather low demand for it. However, this was supposed to be changing as electrolysis would be needed for the production of hydrogen from renewable energy sources and thus both large industrial companies as well as small wind power enterprises have taken up the development of improving the efficiency of electrolysis. Consequently, the efficiency of hydrogen production was to improve over the next couple of years.

In addition to this improvement of the efficiency of hydrogen production, the supporters of H & FC argued that H & FC and battery electric vehicles serve different segments of the car market and that the battery electric vehicle is not the benchmark for alternative drivetrain technologies and fuels. Rather, the internal combustion engine powered by gasoline constitutes the conventional technology that dominates the market and that has to be replaced in order to reduce the emissions caused by the transport sector. Therefore, the efficiency of H & FC vehicles should be compared to that of vehicles with an internal combustion engine and this comparison would show that H & FC constitute the more efficient drivetrain technology. This line of argument is exemplified by the following quotation of a representative of a large private enterprise:

> “At the moment we have an efficiency rate of 65% for the electrolysis and the developers are telling us that it can be increased by around 10% so that we would have 75%. The fuel cell has an efficiency rate of around 50% so that we would have an overall efficiency rate of 40% which is, of course, lower than that of the battery, if applied in a car, but still clearly better than an internal combustion engine with an efficiency rate of less than 20%.” (Interviewee 15, 2012)

In addition, the supporters of H & FC have also used the specific expertise produced to underpin that no single technology can cover all the needs of the future transport sector but rather different technologies will have to serve different purposes. In subchapter 9.2.2 it has been illustrated how the scientists of the JRC highlighted that in order to achieve driving ranges beyond 400 km the weight of the battery would increase disproportionately high to the power increases that would be achieved by a larger battery system. Hence this expertise was fed into the policy discourse to defend H & FC against the critique from the supporters of the battery technology as the following quotation of an official of the EC illustrates:

> “I mean the battery is already 300-400 kilogram for the range of 150 km that you rarely use. With improvement in the battery you could have maybe 400-500 kilogram for 500 km. We are not there yet, but even if we could, does it make sense to carry? I mean if you had such a technology it would mean that the battery for doing 150 km would

> weigh 150 kilogram and you would save 200 kilogram on the car and this would save the energy all over the life of the vehicle. So it is a trade-off." (Interviewee 14, 2013)

Thus the main argument was that H & FC are much better suited than battery electric vehicles to power larger passenger cars and cars that are used for distances longer than 500 km. Furthermore, it was argued that these large passenger cars with a long driving range will still be needed in the future because many people would not be willing to change their habits and to switch to smaller cars and to drive shorter distances. So, assumed that many people would not be willing to change their habits, H & FC were to be the only technology that shows the potential of allowing maintaining the current patterns of mobility while reducing the emissions resulting from them.

In addition to the short driving ranges also the time needed to recharge battery electric vehicles was highlighted in order to illustrate the superiority of H & FC vehicles in that respect. The time required for recharging battery electric vehicles was to take up to eight hours if slow recharging technologies are applied and 20-30 minutes if fast recharging technologies are used. In contrast, it would only take a few minutes to refuel fuel cell vehicles with hydrogen which would thus be much faster and more similar to refuelling gasoline or diesel cars. Hence H & FC vehicles would allow the consumers to maintain flexibility in terms of driving ranges and to maintain the comfort of short refuelling times while simultaneously reducing the emissions in the transport sector.

Therefore, one of the main arguments of the discourse coalition for the continuation of H & FC was that there will not be any single technology that meets all the different requirements of the transport sector. Rather, a portfolio of different technologies will be needed that should be developed in parallel. This view was underlined by the specific expertise produced in the expertise discourse on H & FC in order to highlight a complementary relationship between the different drivetrain technologies and fuels. The following quotation of a scientist of a public research institution illustrates how the supporters of H & FC argued that biofuels, electricity, and hydrogen will fulfil complementary roles in a future emission-free transport system:

> “You do not have enough biofuels for all the cars and all the applications, airplanes and so on. So if you have not enough oil and not enough biofuel, the only solution is the electric car. So if you look at the possibility of the electric car, it is battery or fuel cell. So my opinion is, but I can of course never know what will happen on the scientific level, if there is not a breakthrough on the batteries and even with small improvement of the batteries, 10 %, 20 %, 50%, the batteries will never cover more than 10% of the needs. So what is the solution, it is hydrogen and fuel cells.” (Interviewee 8, 2012)

The quotation above also exemplifies how the supporters of H & FC used the expertise produced in the expertise discourse on H & FC in order to defend H & FC against the critique of the supporters of the battery technology in the policy discourse. In a similar way, the expertise produced was also applied to meet the scepticism of the commercialization of H & FC and the safety concerns as will be outlined in the following paragraphs.

*Meeting the scepticism of the commercialization of H & FC and the safety concerns*

The different supporters of the discourse coalition for the continuation of the FCH JU attempted to resolve the scepticism of those officials of the EC who claimed that H & FC vehicles will not enter the market anytime in the short-term future. While the supporters of H & FC acknowledged that it takes a lot of time to develop a new technology, they also argued that significant improvements have been achieved in the development of H & FC in terms of reducing costs, increasing efficiency, extending the lifetime etc. The main point was to outline that the development of H & FC has progressed significantly but that still further funding is needed in order to achieve the commercialization of H & FC vehicles which is closer than it was ever before. The following quotation of an official of the EC exemplifies this line of argument:

> "It is sure that some people think that the money spent on hydrogen is too much because the industry says that the vehicles are more or less ready. There are for sure improvements because nobody can say with a serious face that in 10 years hydrogen has reached the level that engines have reached in 100 years, it would not be serious. So its mature enough as a starting point but of course there is plenty of research that you could improve a lot of things, but it is sellable in a way." (Interviewee 14, 2013)

Furthermore, the supporters of H & FC emphasized that some H & FC technologies already have been commercialized which was to indicate that a broader market for H & FC will emerge soon. In order to underline that a H & FC market is developing, the supporters of H & FC highlighted the niche markets that have evolved for H & FC applications in other countries as following quotation of an official of the EC illustrates:

> "This has changed now and we have different niche markets that are developing. We have tens of thousands of boilers in houses in Japan. This was not true five years ago, there was nothing. You have a few thousands of forklifts working with H & FC in the US. That are the last few years. So something is happening, that is my interpretation. ... If I look at some years ago when the people were saying we have been promised for decades and it has not happened until today, my answer is look, did you have tens of thousands of units in Japan and boilers back then? You have it now so that means that something is happening and that is when people say ok." (Interviewee 11, 2013)

The supporters of H & FC deployed two main strategies to resolve the safety concerns with regard to hydrogen. First, it was attempted to increase the public awareness of H & FC in various projects. Public demonstration projects were carried out in which hydrogen powered fuel cell buses were integrated into the regular fleets of the public transport companies in different cities. Furthermore, there have been different projects in which the citizens have been invited to drive a hydrogen powered fuel cell car. In addition, education material on H & FC for public schools has been developed and various information events for the broader public have been held. All of these activities were to spread the message that a lot has been done and is being done to ensure the safety of hydrogen tanks in vehicles.

The second strategy was to put the perceived danger of hydrogen into relation to the danger of other technologies. When critics pointed out that hydrogen is extremely flammable and that hydrogen tanks in vehicles could explode in case of accidents and crashes, then the proponents of H & FC replied that this is exactly what is happening with gasoline and diesel, too, and that this still does not stop anyone from driving these cars. Furthermore, the potential danger of other alternative energy technologies such as batteries was pointed out by referring to the issue of the Boeing 787 Dreamliner airplanes in which lithium-ion batteries appear to have caused electrical fires on board of several flights in 2012 and 2013 after which airplanes of this model have been taken out of operation for further investigations. Hence the main point was that H & FC are neither more dangerous than the technologies that are already used nor than other alternative energy technologies that might be applied for vehicles propulsion in the future.

### 9.3.4 Proving the need of continuation of the FCH JU: The Impact Assessment

This subchapter is to explain how the Impact Assessment accompanying the proposal of the EC for the launch of the FCH 2 JU was conducted. The conduct of the Impact Assessment was a bureaucratic exercise in which the supporters of H & FC in the EC, the JRC, and in the public and private organizations involved in the FCH JU advocated their view of the continuation of a modified FCH JU in Horizon 2020 being the best policy option available for the further promotion of H & FC to further officials of the EC. Thus, in contrast to the broader policy discourse on H & FC, the conduct of the Impact Assessment was less about legitimizing the promotion of H & FC *per se* but rather about outlining the advantages of the continuation of a modified FCH JU over other policy options. For this purpose, the supporters of H & FC used the specific expertise that they had developed in the expertise discourse on H & FC. Consequently, the main result of the Impact Assessment was the conclusion that the continuation of a modified FCH JU is the best policy option available for the further promotion of H & FC in Horizon 2020.

To explain the conduct of the Impact Assessment in more detail, the subchapter at hand is split into two subheadings. First, the formal procedure and the results of the Impact Assessment are described. Second, it is explained how these results came into being in a process in which the supporters of H & FC advocated the advantages of the continuation of a modified FCH JU over other policy options to further officials of the EC.

*The formal procedure and the results of the Impact Assessment*

In July 2013 the EC published the report of its Impact Assessment (hereinafter IA) on the launch of the FCH 2 JU. While more than ten DGs have been officially involved in the conduct of the IA and were provided with the opportunity to give their opinion on it, the leading DG was R&I and most of the support it received came from DG ENER, DG MOVE, and the JRC. During the conduct of the IA, the policy and scientific officers of DG R&I consulted the private enterprises of the NEW IG, the public research institutes and universities of the N.ERGHY Research Grouping, the Member States representatives, and the Programme Office of the FCH JU as well as the general public (European Commission 2013a, 2). Furthermore, the Impact Assessment Board had expressed its opinion on the IA and three independent experts were involved in the development of the IA; two of which have already been involved in the conduct of the First Interim Evaluation (European Commission 2013a, 3, 35).

The conduct of an IA was a bureaucratic exercise formalized through the general guidelines of the EC for its Impact Assessments which have already been explained in more detail in subchapter 7.3.4. According to these general guidelines, the report of the IA focuses on four main issues which are the definition of the problem that is to be tackled by the further promotion of H & FC, the statement of the objectives that are to be achieved by this promotion, the identification of the policy options available for the promotion of H & FC in Horizon 2020, and the comparison of these different policy options.

The main problem that was to be tackled through the further promotion of H & FC was the market failure that prevents the commercialization of H & FC which are portrayed as key technologies of the future that can contribute to fighting climate change, increasing the EU's energy security, triggering economic growth, and creating new jobs. However, the existence of a market failure is to prevent H & FC from achieving their full potential in contributing to solving these wider societal challenges. The main point was that the investments required for the development of H & FC are to be of a scale that cannot be managed by individual Member States on their own. In addition, the investments of private companies were to be hampered because of the high risks of the development and the insecure prospects of a return on investment (European Commission 2013a, 5-15). Therefore, it was concluded that a coordinated EU approach in the form of a FCH 2 JU is needed to provide the stable financial framework that is required to reduce risks, to trigger investments, and to coordinate the actions of the different actors involved.

The general objective of such a FCH 2 JU was to be the development of a globally competitive European H & FC sector that contributes to the achievement of the objectives of EU climate, competitiveness, energy, and transport policy. Also more specific technical objectives were defined such as, among others, the reduction of the costs of production of fuel cells for transport applications, the increase of the efficiency and the durability of fuel cells used for power production in the stationary sector, the increase of the efficiency of hydrogen production via electrolysis, and the demonstration of the capabilities of hydrogen as a storage medium for renewable energy sources on a large scale (European Commission 2013a, 15-17).

After discarding the policy option of no-EU action because H & FC are not yet sufficiently mature to enter the market, four policy options were chosen for further comparison: 1) continuing the FCH JU as it is, 2) collaborative research projects under FP 8, 3) contractual public private partnership, and 4) modernized FCH JU (European Commission 2013a, 17). These four policy options were compared with each other by eleven criteria: 1) well-designed intervention logic, 2) leveraging effect on deployment, 3) critical mass, 4) small and medium-sized companies, 5) innovation, 6) economic growth and competitiveness, 7) coherence of the knowledge triangle, 8) broader policy coordination, 9) coherence with programmes of Member States, 10) cost efficiency, and 11) operational simplicity (European Commission 2013a, 22-28).

Eventually, it was concluded that the policy option of a modernized FCH JU that is to say a FCH 2 JU was to be either superior or equal in all eleven criteria to a mere continuation of the FCH JU and to the launch of a contractual public private partnership. Furthermore, a modernized FCH JU was to be superior to the policy option of collaborative research projects under FP 8 in almost all criteria. In addition, the policy option of a modernized FCH JU was to be the preferred option of the stakeholders and in particular of the industrial companies of the NEW IG who claimed that a modernized FCH JU would be the policy option with the strongest impact on the development of the H & FC sector (European Commission 2013a, 28).

Hence a modernized FCH JU that is to say a FCH 2 JU was concluded to be the most suitable policy option for the further promotion of H & FC in Horizon 2020. The continuation of a modified FCH JU should ensure that H & FC achieve their full potential and contribute to the achievement of the broader EU policy objectives in the future. Furthermore, concrete technical objectives that were to be reached by 2020 were defined and performance indicators such as the public and private investments in H & FC triggered by the FCH 2 JU were suggested in order to monitor and evaluate the progress in H & FC and the impact of the FCH 2 JU (European Commission 2013a, 33, 34).

*The conduct of the Impact Assessment*

The results of the IA outlined above were mainly brought about by the officials of DG R&I, DG ENER, and DG MOVE, the scientists of the JRC and the representatives of large private enterprises who were supportive of H & FC. These actors used the specific expertise that they had produced in the expertise discourse on H & FC in order to advocate the future potential of H & FC and the right means to achieve this potential to other officials in the EC. Based on this expertise, the supporters of H & FC highlighted the importance of these technologies for the achievement of the wider EU policy objectives, outlined why the EU had to act in the area of H & FC, and underlined that the continuation of a modified FCH JU is the best policy option available for the further promotion of H & FC in Horizon 2020. Hence the conduct of the IA was a bureaucratic exercise in which the supporters of H & FC advocated their view that the continuation of a modified FCH JU constitutes the best policy option available for the promotion of H & FC in Horizon 2020 to other officials of the EC. For this purpose, the supporters of H & FC had to respond to the comments and to resolve the doubts of all the other officials of the EC involved in the IA as will be illustrated in the following paragraphs.

The assessments on how many jobs the development of H & FC might create in the future constituted for instance one issue that was discussed in the conduct of the IA. The supporters of H & FC used these assessments to underline how H & FC can contribute to the EC's objectives of increasing competitiveness, generating economic growth, and creating new jobs or preserving existing ones. However, other officials of the EC were sceptical of the assessments and studies put forward by the supporters of H & FC to underline their claims. The following quotation of an official of the EC exemplifies how the issue of the concrete number of the jobs that can be expected in the area of H & FC in the future was discussed in the conduct of the IA:

> "In the group we had one very good expert who knew about micro-economics and policy etc. He was not necessarily a fuel cell expert and he said that creating jobs depends very much on micro-economic policies and not on industrial policy. So he was very sceptical with the American studies. … Fair enough, but we also have to explain to those that take the decisions in the EC and in the EP that the Americans have very optimistic projections and that might be an indicator that something is happening so we cannot afford to miss the opportunity." (Interviewee 11, 2013)

The discussion on how many jobs could be expected in the area of H & FC in the future illustrates how contradictory views of the supporters of H & FC and the other officials of the EC were dealt with if a common view could not be achieved. In these cases the different views that could not be settled were described in the final report of the IA. In the case of the different assessments of how many jobs could be expected in the area of H & FC in the future the final report of the IA outlines how many jobs would be created in a more pessimistic and in a more optimistic scenario (European Commission 2013a, 7). The main purpose of this was to show the reader of the IA that there are different assessments on the future economic impact of H & FC so that he or she can make up on his or her own what scenario seems most likely.

In contrast, the issue of niche markets constitutes a good example of how critique on the view put forward by the supporters of H & FC could be resolved through the provision of further expertise. In the conduct of the IA some officials of the EC wondered why the existing FCH JU promotes an area of applications consisting of niche products of H & FC. These officials questioned whether those niche products actually could contribute to achieving the wider EU policy objectives such as the reduction of GHG emissions. This critique was resolved through the provision of further information by the supporters of H & FC highlighting that niche products might not contribute much to a reduction in GHG emissions but that they increase the visibility of H & FC and the citizens' awareness of these technologies and hence fulfil an important role in the overall development of H & FC. The following quotation of a scientist of the JRC outlines the different lines of argumentation:

> "Then there are people who discuss on why is in the current Joint Undertaking the application area for the niche markets. Niche markets do not contribute largely to EU policy goals because it does not really serve the purpose of reducing $CO_2$ emissions if I use a fuel cell forklift truck in a store. For instance, also when I power my PC with a fuel cell based on methanol it does not really matter for GHG emission reduction on the global scale. … So what is the value then of having niche applications in the work programme of the Joint Undertaking? Well, they are the first demonstrators, they are the first proves of principle and they are creating the awareness of the general public of this novel technologies. So there is a reason for having them there." (Interviewee 9, 2013)

Hence the promotion of niche applications has been kept in the final report of the IA in which niche products such as forklifts and small back-up power units are even mentioned as some of the main achievements of the existing FCH JU that has contributed to their successful commercialization (European Commission 2013a, 12).

In order to assert their view of the continuation of a modified FCH JU being the best policy option available for the further promotion of H & FC in Horizon 2020, the supporters of H & FC used the expertise that they had developed in the expertise discourse on H & FC. Indeed, the final report on the IA relied above all on the following reports: 1) First Interim Evaluation of the Fuel Cell & Hydrogen Joint Undertaking, 2) International Energy Agency 2012 Energy Technology Perspective, 3) Technology Map 2011 of the JRC, 4) NEW IG Financial and Technology Outlook 2014-2020, 5) Fuel Cell Today "Industry Review" 2010, 2011 and 2012, as well as the "Patent Review", 6) The McKinsey reports "Pathways to a Low Carbon Economy" (2009) and "A portfolio of power-trains for Europe: a fact-based analysis"

(2010), 7) Pike Research, "Fuel Cells Annual Report 2012" and "Ten Trends to Watch in 2012 and Beyond" (European Commission 2013a, 2).

Hence the IA relied above all on the reports and studies that have been compiled by the supporters of H & FC. The compilation of the Technology Maps of the JRC, of the Financial and Technology Outlook 2014-2020, and of the McKinsey report “A portfolio of power-trains for Europe” have been explained in subchapter 9.2. The development of the First Interim Evaluation report by a panel of independent experts in cooperation with the officials of the EC has been explained in subchapter 8.3. The Fuel Cell Today industry and patent reviews were developed by the British chemicals and precious metals company Johnson Matthey plc which also is a member organization of the NEW IG.

In addition to the expertise that the supporters of H & FC had developed in the expertise discourse on H & FC, further information was collected from the public press and from studies and reports from other countries. In particular, the studies and reports of the Department of Energy in the USA were considered by both the officials of the EC and the representatives of private enterprises as an important source of expertise and of scientific authority. In fact, the way in which the Department of Energy disseminates the scientific results from the projects conducted was perceived by both the officials of the EC and the representatives of private enterprises as a role model for the EU as illustrated in the following two quotations of an official of the EC and a representative of a private enterprise:

> “The information on the new products on the market I have from the press, from the industrial partners or also an excellent source of information is the Department of Energy in the United States which is much better than us. So that is our target for improving our dissemination of results in Europe, trying to approach the Department of Energy.” (Interviewee 11, 2013)

> “How that should be done, if you spend tax money and you have to communicate that, this can be seen in the Annual Review Meeting of the Department of Energy which is published in the USA each year since fifteen years in April or in May and which you

> can download. There they spend tax money and the large research institutions are financed by 100% and they are automatically obliged to complete dissemination. In each EU-project, also in the FCH JU, you have to submit a publishable summary. I would assume that from FP1 to FP7 we conducted around 3000-5000 hydrogen-related projects and if only 5% of the publishable summaries ever were published somewhere, then this would be a lot. Thus, to start with, a severe criticism, we are incapable of disseminating our knowhow, our knowledge." (Interviewee 5, 2013)

Based on the expertise collected and produced, the supporters of H & FC succeeded in asserting their view of the continuation of a modified FCH JU being the best policy option available for the further promotion of H & FC in Horizon 2020.

### 9.3.5 The policy output: The launch of the FCH 2 JU in Horizon 2020

The supporters of the discourse coalition for the continuation of the FCH JU succeeded in asserting their view of H & FC and of the further promotion of these technologies in Horizon 2020 in the policy discourse. In spite of the critique on the slow progress of the hydrogen economy, the inefficiency of hydrogen production, and the safety concerns on the use of hydrogen as a fuel in vehicles, the decision-makers in the EC supported the continuation of a modified FCH JU in Horizon 2020. This was mainly the achievement of the high-ranking officials in DG R&I, DG ENER, and DG MOVE and the representatives of large private companies such as car manufacturers, oil companies, and energy utilities who had good access to the decision-makers in the EC and who used the expertise developed to advocate the continuation of the FCH JU to these decision-makers. These policy entrepreneurs used the expertise produced in the expertise discourse on H & FC in order to defend H & FC against its critics in the policy discourse and to underline that the continuation of a modified

FCH JU constitutes the best policy option available for the further promotion of H & FC in Horizon 2020 in the Impact Assessment.

As a result, the EC published its proposal to set up the Fuel Cell & Hydrogen 2 Joint Undertaking (hereinafter FCH 2 JU) as a legal entity under Article 187 of the Treaty establishing the European Community on 10th July 2013 (European Commission 2013i). The proposal was adopted by the Council of the EU which on 6th May 2014 legally established the FCH 2 JU for the period of time until 31 December 2014 (Council of the European Union 2014). The financial contribution of the EU to the FCH 2 JU was decided to be € 665 million (Council of the European Union 2014, 112).

In addition, the policy entrepreneurs also succeeded in anchoring their view of H & FC in the transport policy of the EC. In January 2013 the EC has published both its Communication "Clean Power for Transport: A European alternative fuels strategy" and its Proposal for a "Directive of the EP and the Council on the deployment of alternative fuels infrastructure". The Communication outlines liquefied petroleum gas, natural gas (encompassing both liquefied and compressed natural gas), electricity, biofuels, and hydrogen as most promising future transport fuels for the substitution of gasoline and diesel in the transport system (European Commission 2013c). In order to encourage the purchase and to facilitate the actual use of vehicles powered by these fuels, the Directive proposes minimum binding targets for the development of national refuelling infrastructures for each of the fuels mentioned. The EC proposes for instance that each Member State is to construct publicly accessible hydrogen refuelling points with distances not exceeding 300 km (European Commission 2013j, 15). Similar objectives are proposed for the development of a minimum Europe-wide refuelling infrastructure for the other four alternative fuels in order to enable the drivers of vehicles powered by alternative fuels to travel throughout the EU without constrains.

Both the Communication and the Proposal for the Directive are based on the two reports of the Expert Group on Future Transport Fuels whose development was explained in detail in subchapter 9.2.2. The high-ranking officials of EC and the representatives of large private companies who are supportive of H & FC succeeded in asserting their view of a complementary relationship between the different drivetrain technologies and fuels in the two expert reports. H & FC were described as the most suitable technologies for larger passenger cars and longer driving distances in the reports of the Expert Group on Future Transport Fuels. Based on the expertise outlined in those two reports and their good access to the decision-makers in the EC, the policy entrepreneurs promoting H & FC succeeded in establishing a specific role for these technologies in the transport policy of the EC as illustrated by the Communication and the Proposal for a Directive of the EC published in 2013.

## 9.4 Conclusions

This chapter explained the launch of the FCH 2 JU by the Council of the EU in May 2014 as the final result of a process of co-production of policy and expertise in the years of 2011-2014. The main point was to outline that this process was embedded in the wider negotiations of Horizon 2020 and characterized by the policy stages of agenda-setting and decision-making of the policy cycle model. Hence the theoretical framework of this thesis was applied to highlight how the supporters of H & FC attempted to keep these technologies on the European agenda and to achieve the continuation of the FCH JU. For this purpose, the more general expertise required to raise political attention to H & FC was developed as well as the more specific technical expertise required to outline the specific role of H & FC in relation to other alternative drivetrain technologies and fuels. H & FC were portrayed as clean new energy technologies that will contribute to the achievement of the broader objectives of EU innovation, energy, and transport policy such as economic growth and emission reduction. In addition, the concrete technical advantages of H & FC over the battery technology as a propulsion system for larger passenger cars and longer driving distances were outlined. This expertise was used to raise political attention for keeping H & FC on the

European agenda and to legitimize the political decision to continue the FCH JU in a modified version in Horizon 2020.

The interpretation of the empirical data collected for this thesis has also shown that the co-production of policy and expertise that resulted in the continuation of the FCH JU was most influenced by policy entrepreneurs with specific resources such as high-ranking officials at the Director or Director-General level of different DGs of the EC including the JRC and representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities. These policy entrepreneurs linked the two discourses of policy and expertise to each other and played key roles in the production of expertise on H & FC and in advocating the continuation of the FCH JU in Horizon 2020 to the decision-makers in the EC. Their resources in the form of hierarchical position, time, and financial means enabled the policy entrepreneurs to lead the production of expertise on H & FC and to transfer this expertise into the policy discourse. In addition to these resources, the position of the large private enterprises in the production of expertise was further strengthened through the EC's general understanding of innovation. Many officials of the EC regarded innovation primarily as the development of new commercial products which should be led by industrial actors.

Hence, due to their resources and the EC's general understanding of innovation, the as high-ranking officials at the Director or Director-General level of the EC and the representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities played key roles in the expertise discourse on H & FC. Above all their hierarchical positions in the EC and in the large private enterprises enabled the policy entrepreneurs to slip into the role of experts and to assert their views on H & FC in the different expert authorities of the EC such as the Expert Group on Future Transport Fuels and the Strategic Energy Technology Information System of the JRC. In this way, these policy entrepreneurs succeeded in establishing their view of a complementary relationship between H & FC vehicles, battery electric vehicles, and plug-in hybrids in the different expert authorities of the EC and to outline a specific role for H & FC in a future emission-free transport system with regard to the other alternative drivetrain technologies and fuels. H &

FC were portrayed as the best drivetrain technologies and fuel for larger passenger cars and longer driving distances.

Due to their resources, the policy entrepreneurs also had a better access to the decision-makers in the EC which enabled them to use the expertise produced in order to advocate the continuation of the FCH JU in Horizon 2020 to the decision-makers in the EC. Above all the officials at the Director-General level in DG R&I, DG ENER, and DG MOVE had direct access to the Commissioners for Research, Energy, and Transport and advocated the continuation of the FCH JU to these and to their colleagues at the same hierarchical level in other DGs of the EC. In addition, also the representatives of the large private enterprises such as car manufacturers, oil companies, and energy utilities had direct access to the decision-makers in different DGs of the EC and used the expertise produced on H & FC to advocate the continuation of the FCH JU in Horizon 2020. Hence the policy entrepreneurs of the EC and the large private enterprises transferred the expertise produced on H & FC into the policy discourse and used it to promote the continuation of the FCH JU in the eighth FP of the EC and to defend H & FC against critique.

As a result of this process of co-production of policy and expertise the EC published its proposal on the launch of the FCH 2 JU in July 2013 (European Commission 2013i). This proposal was adopted by the Council of the EU in May 2014 so that H & FC continue to be a part of the European research and innovation policy and are promoted through one of several public private partnerships under Horizon 2020 Council of the European Union, „Coucil Regulation (EU) No 559/2014 of 6 May 2014 establishing the Fuel Cells and Hydrogen 2 Joint Undertaking (Text with EEA relevance)“.. Furthermore, H & FC became part of the EU transport policy and the EC proposed the build-up of a European refuelling infrastructure for hydrogen and other alternative fuels in its Proposal for a "Directive of the EP and the Council on the deployment of alternative fuels infrastructure" (European Commission 2013j).

These developments constitute the last bits in the co-production of EU H & FC policy and expertise in the years of 2000-2014 that was analyzed in this thesis. The chapter at hand and the three preceding chapters have outlined the empirical results of this analysis. For this purpose, the policy cycle model was applied to categorize the co-production of EU H & FC policy and expertise in the years of 2000-2014 into four different stages, each of which was shaped by the logics of different stages in the policy process. Finally, the next and last chapter of this thesis will summarize the main empirical findings and elaborate what broader conclusions can be drawn from this case study of the co-production of EU H & FC policy and expertise.

# Part IV

# Conclusions

# 10 What can be learnt from the case of EU hydrogen and fuel cell policy and expertise?

This chapter provides a synthesis of the findings of this thesis which set out to shed light on the innovation turn in European research policy through an explorative case study of the co-production of policy and expertise in the promotion of hydrogen and fuel cell technologies in the EU. The promotion of these alternative energy technologies exemplifies the innovation turn in EU research policy that was initiated by the Lisbon Council in March 2000. H & FC became part of the European innovation agenda when the EC decided to set up a High Level Group that should develop a vision for the future deployment of these technologies in 2002. Subsequently, the development of H & FC was promoted by the new policy instruments of the EC. In 2004 the Hydrogen and Fuel Cell Technology Platform was launched and in May 2008 the Council of the EU set up the Fuel Cell and Hydrogen Joint Undertaking. Most recently in May 2014 the Council of the EU approved the continuation of a modified Fuel Cell and Hydrogen Joint Undertaking in Horizon 2020. All of these political decisions were based on specific expertise on H & FC which was produced in parallel and in relation to them. Therefore, the case of H & FC provides a prime example of the co-production of policy and expertise in the new EU R&I policy after the Lisbon Council.

In order to investigate this case this thesis put forward an innovative theoretical framework drawing on insights from the Science and Technology Studies and the Discourse Coalitions approach and the concept of the policy entrepreneur from the Public Policy literature. In this way it overcame the flaw of many Public Policy approaches that only implicitly take into account the role of scientific information in the form of external factors. In contrast, the theoretical framework developed speaks of the co-production of policy and expertise assuming that both are produced together and in relation to each other. This incorporation of the production of expertise into the policy subsystem constitutes the main theoretical innovation of this thesis with regard to the wider Public Policy literature. In addition to this theoretical innovation, this thesis constitutes one of the few empirical studies of the new EU R&I policy launched after the Lisbon Council contributing to a deeper understanding of this rather rarely explored policy field. Hence both the innovative theoretical framework and the empirical focus of this thesis allowed shedding light on how the European Commission implements it new focus on innovation in practice.

The following subchapters will summarize the main findings of this thesis with regard to these two innovative elements. First, the empirical results will be summarized highlighting the main insights on the co-production of EU H & FC policy and expertise in the years of 2000-2014. Second, it will be elaborated in how far the results from this explorative case study allow for drawing conclusions on the wider EU R&I policy after the Lisbon Council. Third, it will be outlined how the findings of this thesis and its innovative theoretical approach contribute to the scholarly literature on the governance of EU R&I policy that was illustrated in subchapter 2.2. Finally, based on the results of this thesis, opportunities for further research in the fields of Science and Technology Studies and Public Policy will be indicated.

## 10.1 Summary of the empirical results and the main conclusions drawn

This subchapter first provides a summary of the empirical results of this thesis before it elaborates what conclusions can be drawn on the central research question of the co-production of EU H & FC policy and expertise in the years of 2000-2014.

Throughout the empirical chapters 6-9 of this thesis it was argued that two main factors shape the co-production of EU H & FC policy and expertise: 1) The stage of the policy process, and 2) The role played by policy entrepreneurs equipped with specific resources such as financial means and access to decision-makers. Of course, the actual policy process was also shaped by many more factors due to the endless complexity of the empirical reality. However, the theoretical framework of this thesis allowed distinguishing the more important factors from the less important ones. Hence the empirical chapters 6-9 of this thesis focused on illustrating the role of the two main factors identified as these have a higher explanatory value for the co-production of EU H & FC policy and expertise than any others factors. Hence the policy cycle model with its different stages of agenda-setting, policy formulation, decision-making, policy implementation, and evaluation proved to be a useful heuristic tool to highlight the specific dynamics that have defined the dominant policy issues in the co-production of EU H & FC policy and expertise at different points in time. According to these dominant policy issues, specific policy entrepreneurs equipped with the necessary resources to act at the interface of policy and expertise linked the two discourses to each other by producing the expertise required to achieve their political objectives. The empirical findings revealed that these policy entrepreneurs were mainly high-ranking officials of the EC at the Director and Director-General level and representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities. Due to their resources such as financial means and a good access to the decision-makers in the EC, these policy entrepreneurs could assert their views on H & FC in the expertise discourse and use this expertise to advocate H & FC to the decision-makers in the EC in the policy discourse.

The following paragraphs are first to summarize how these two main factors shaped the co-production of EU H & FC policy and expertise. Thereafter, these empirical findings are raised to a higher level of abstraction in order to provide answers to the central research question of this thesis on the co-production of EU H & FC policy and expertise in the years of 2000-2014.

*Summary of the empirical results*

The empirical results of this thesis have illustrated that the co-production of EU H & FC policy and expertise in the years of 2000-2014 can be categorized into four different stages for heuristic purposes. Hence these four stages should be regarded as heuristic tools that have been applied in this thesis to make sense of the complex nature of the co-production of EU H & FC policy and expertise. This implies that the four different stages are not separated by clear-cut boundaries but rather describe a continuous process in which the specific dynamics of each stage of the policy cycle model are present at any point in time but to varying degrees. Thus there are aspects of decision-making in the stage of agenda-setting, dynamics characterizing agenda-setting are present in the stage of evaluation and so forth. However, categorizing the co-production of EU H & FC policy and expertise in the years of 2000-2014 into four different stages constitutes a helpful heuristic tool to highlight the most important issues in the co-production of EU H & FC policy and expertise at specific periods in time.

For this purpose, each of the four empirical chapters of this thesis has focused on outlining one of these four stages in order to illustrate the specific issues that have shaped the co-production of EU H & FC policy and expertise at that period in time. Table 10 illustrates the four different periods in time in the co-production of EU H & FC policy and expertise that have been distinguished in this thesis and outlines how specific policy entrepreneurs have linked the two discourses on policy and expertise to each other according to the dominant policy issue of each period in time:

| **Time Period** | **Dominant policy entrepreneurs** | **Link between policy and expertise** | | **Policy output** |
|---|---|---|---|---|
| | | Dominant policy issue | The expertise produced | |
| 2000-2004 | High-ranking officials in the EC and representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities | Raising political attention | The hydrogen economy | Launch of the Technology Platform |
| 2004-2008 | | Defining objectives and legitimizing decisions | Fuel cells and hydrogen as new, low carbon energy technologies | Launch of the Joint Technology Initiative |
| 2007-2011 | | Influencing the distribution of resources and satisfying bureaucratic needs | Individual views on H & FC | Selection and funding of H & FC projects |
| 2011-2014 | | Raising political attention and legitimizing decisions | H & FC as alternative drivetrain technologies and fuels | Continuation of the Joint Technology Initiative |

**Table 10**, The four different stages in the co-production of EU H & FC policy and expertise

Source: (author's own illustration)

In the chapters 6-9 it has been argued that the co-production of EU H & FC policy and expertise in the years of 2000-2014 was embedded in the different stages of the wider EU R&I policy and that the production of expertise was most influenced by the dominant policy issue in each of the policy stages. Hence this dominance of the policy side over the expertise side is not the result of a bias in the conceptual framework applied but rather a result of the empirical analysis of this thesis which revealed that specific policy entrepreneurs dominated the production of expertise according to their political objectives. Due to their resources such as financial means, time, and a good access to the decision-makers in the EC, these policy entrepreneurs had more impact on the different dimensions in the production of expertise than other actors. In fact, these resources enabled specific policy entrepreneurs such as high-ranking officials in the EC and representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities to establish themselves as experts in official expert groups of the EC as well as to act as experts in informal meetings with the decision-makers in the EC. In this way these policy entrepreneurs could establish the expertise they needed according to the dominant policy issue of each stage in the co-production of EU H & FC policy and expertise. Consequently, they embedded the expertise established in specific story lines which they promoted in the policy discourse to mobilize broad discourse coalitions for their political objectives as explained in more detail in the following paragraphs.

First, in the stage of agenda-setting in the years of 2000-2004 expertise was developed to raise political attention for specific technological areas in order to make these part of the new European innovation agenda. For this purpose, the vision of the hydrogen economy highlighted the future potential of H & FC for creating new jobs and reducing GHG emissions in rather general terms. The main objective was to attract the interest of the policy-makers of the EC which required illustrating the promising future prospects of H & FC rather than outlining a concrete development programme.

The development of the vision of the hydrogen economy was mainly driven by policy entrepreneurs who were equipped with the necessary resources to dominate the production of expertise and to transfer the vision of the hydrogen economy into the policy discourse. The most important policy entrepreneurs in the first stage of the co-production of EU H & FC policy and expertise were the then Commissioner for Research, Philippe Busquin, high-ranking policy officials of the EC at the Director and Director-General level, and the representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities. While also scientists from public research institutes or representatives of SMEs were involved in the production of expertise, it was the policy entrepreneurs who had most influence upon the development of the vision of the hydrogen economy due to their resources in the form of time, financial means, and good access to the decision-makers in the EC. Hence these resources allowed the representatives of large private enterprises to act as the key experts and to assert their views on H & FC in the development of the vision of the hydrogen economy. In so doing, they were supported by the specific understanding of innovation of many officials of the EC who mainly regarded innovation as the development of new economic products. This enabled the representatives of large private enterprises to become the key experts on H & FC and to play key roles in the development of the hydrogen economy as mainly they would possess the financial resources to make the huge investments required to lead H & FC to commercialization.

These specific resources of the policy entrepreneurs also enabled them to transfer the vision of the hydrogen economy into the policy discourse and to gather political support for it. The representatives of large private enterprises often have a direct access to the decision-makers in the EC which is not granted to scientists of public research institutes or to representatives of smaller companies. In addition, actors inside of the EC such as the then Commissioner for Research, Philippe Busquin, and high-ranking officials of DG R&I and DG

TREN at the Director and Director-General level promoted the vision of the hydrogen economy. Above all Philippe Busquin could due to his own position as the Commissioner for Research advocate H & FC directly to the then President of the EC, Romano Prodi, and the then Commissioner for Energy, Loyola de Palacio. In contrast, the critique of the hydrogen economy was rather marginal and only raised by individual MEPs of the group of the Greens/European Free Alliance and by representatives of environmental NGOs who criticized hydrogen production as inefficient and as not ecological *per se*. However, the decision-makers in the EC did not share this critique. Consequently, the EC launched the Hydrogen and Fuel Cell Technology Platform in 2004.

Second, in the stage of policy formulation and decision-making in the years of 2004-2008 expertise was produced to legitimize the launch of a Joint Technology Initiative for H & FC. This required the definition of a concrete development programme for H & FC and the embedding of H & FC in the broader objectives of EU energy policy. Hence H & FC were embedded in FP 7 as new, low carbon energy technologies and concrete targets for their development have been defined with the Snapshot 2020 objectives. These should be achieved by the concrete development programme for H & FC as outlined in the Strategic Research Agenda, the Deployment Strategy, and the Implementation Plan that were developed in the Hydrogen and Fuel Cell Technology Platform. In addition, further expertise was developed in various other H & FC projects funded by the EC under FP 6 that underlined the potential of H & FC to reduce $CO_2$ emissions in the future and that compared H & FC with other new energy technologies.

The different dimensions in the production of this expertise on H & FC were dominated by policy entrepreneurs with specific resources such as financial means and a good access to the decision-makers in the EC. Due to these resources the high-ranking officials at the Director and Director-General level of the EC and the representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities had more influence about the development of expertise than other actors from NGOs, SMEs, or public research institutes. Above all the representatives of the large private enterprises could establish themselves as experts on H & FC in both informal relationships and in formal expert groups and assert their views on these technologies. They advocated their views on H & FC not only to the officials of the EC but also to the public research institutes and the other private enterprises in the expertise discourse. In so doing, they ensured not only that the expertise produced on H & FC is consistent across the different studies and reports but also that it can be used in the political discussions of the launch of the Joint Technology Initiative and in the Impact Assessment that has to be conducted to prove that the launch of a Joint Technology Initiative is the best policy option available. Consequently, H & FC were portrayed as one among other new, low carbon energy technologies that can contribute to the achievement of the EU's climate and energy policy objectives of reducing $CO_2$ emissions.

In this way the policy entrepreneurs linked the two discourses on policy and expertise to each other by producing the expertise that they would need to justify the launch of a Joint Technology Initiative and by transferring this expertise into the policy discourse. In the Impact Assessment the expertise was used to demonstrate that the launch of a Joint Technology Initiative for the promotion of H & FC in FP 7 is the best policy option available. By promoting H & FC as new, low carbon energy technologies the policy entrepreneurs also gathered further support for the launch of a Joint Technology Initiative in the wider policy discourse. However, in contrast to the first years of the new millennium, H & FC had lost one of their most active and influential advocates in the EC in the years of 2004-2008 as the Commissioner for Research, Philippe Busquin, left the EC and became a Member of the European Parliament in 2004. Still, many of the promoters of H & FC were high-ranking officials at the Director and Director-General level in DG R&I and the then DG TREN which was split into DG ENER and DG MOVE in 2010. These high-level senior officials advocated H & FC to their colleagues on the same hierarchical level in the EC and to the Commissioners for Research, Energy, and Transport. In addition, also the representatives of large private enterprises had direct access to the decision-makers in the EC and advocated the launch of a Joint Technology Initiative for H & FC to these. Furthermore, these policy entrepreneurs of the EC and the large private enterprises used the expertise produced to counter the critique of the supporters of the battery technology and to portray H & FC as one among other new, low carbon energy technologies that will all be needed to achieve the desired reductions in $CO_2$ emissions in the future. The other decision-makers in the EC followed this line of argumentation and proposed the launch the Fuel Cell and Hydrogen Joint Undertaking which was adopted by the Council of the EU in May 2008.

Third, in the stage of policy implementation and evaluation in the years of 2007-2011 the production of expertise was first affected by many different actors who put forward specific expertise in order to influence the distribution of resources during the implementation of the Fuel Cell and Hydrogen Joint Undertaking and thereafter by the internal bureaucratic logics of the EC during the first interim evaluation of the Fuel Cell and Hydrogen Joint Undertaking. While in previous years the shared objective of setting H & FC on the agenda and of launching the Fuel Cell and Hydrogen Joint Undertaking enabled many different actors to agree upon specific expertise on H & FC by which they could promote these technologies, the distribution of the resources that have become available through the launch of the Fuel Cell and Hydrogen Joint Undertaking triggered a more strategic use of specific expertise by each individual actor involved. The representatives of the different private and public organizations involved in the Fuel Cell and Hydrogen Joint Undertaking attempted to approach the officials of the EC individually in order to persuade them of the relevance of their specific technological area of interest for the overall development of H & FC. Hence each individual actor tried to increase his or her expert reputation at the EC and to secure the highest amount possible of the overall budget available for his or her technological areas of interest by underlining his or her arguments with specific expertise on H & FC.

In addition to the competition for the financial resources, the implementation of the Fuel Cell and Hydrogen Joint Undertaking also caused competition for influence in the governance of this new institution. While public research institutes and smaller companies only played a minor role in this competition, the main discussions were led by the representatives of large private companies and the senior officials of the EC who had different views on the evaluation procedure of project proposals for funding and on the selection of the staff for the Fuel Cell and Hydrogen Joint Undertaking. In addition to these different views, the selection of the staff was further delayed by the complex regulations for staff selection and employment of the EU that had to be applied. Altogether these different issues resulted in a delay of more than two years in the completion of the staff selection with the consequence that the Fuel Cell and Hydrogen Joint Undertaking could not perform all the tasks that it was supposed to perform.

The first interim evaluation of the Fuel Cell and Hydrogen Joint Undertaking was conducted by an expert panel selected by the officials of the EC according to the EC's general criteria for expert selection (EC 2010b, 10, 11; FCH JU 2008c, 7). The officials of the EC maintained close contact to the expert panel during the evaluation and ensured that the Fuel Cell and Hydrogen Joint Undertaking is evaluated on the basis of the same criteria as the other four Joint Technology Initiatives so that comparable results are produced that allow the EC to assess the operation of the different Joint Technology Initiatives in relation to each other. In addition, the senior officials of the EC also exerted a degree of pressure on the expert panel to recommend that the Fuel Cell and Hydrogen Joint Undertaking should be continued in FP 8 as this recommendation would be of use in the upcoming political negotiations of FP 8. This pressure gave rise to controversy among the experts who had very different views on the operation of the Fuel Cell and Hydrogen Joint Undertaking and on the future potential of H & FC in general. Eventually, the expert panel decided to recommend the continuation of the Fuel Cell and Hydrogen Joint Undertaking. Hence the conduct of the first interim evaluation was much influenced by the internal, bureaucratic requirements of the EC as a public administration.

Fourth, the years of 2011-2014 were characterized by the dynamics of the stages of agenda-setting and decision-making. The negotiations on Horizon 2020 were taking place and the supporters of H & FC attempted to secure the continuation of the Fuel Cell and Hydrogen Joint Undertaking in FP 8. For this purpose, the expertise needed to outline in an Impact Assessment that the continuation of a modified Fuel Cell and Hydrogen Joint Undertaking is the best policy option available for the promotion of H & FC was developed.

Furthermore, the potential of H & FC to contribute to the achievement of EU innovation, energy, and transport policy objectives was highlighted in order to raise attention to these technologies and to legitimize their further promotion in Horizon 2020.

The development of this expertise was mainly driven by the policy entrepreneurs who were equipped with the necessary resources such as financial means and a good access to the decision-makers in the EC that enabled them to act at the interface of policy and expertise and to link these two discourses to each other. The high-ranking officials of the EC and the representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities achieved in various expert authorities of the EC that H & FC vehicles, battery electric vehicles, and plug-in hybrids are portrayed as the most promising options to achieve a future sustainable mobility and that all of these three technologies will be needed as they will serve different segments of the car market. In addition, hydrogen was outlined as a means for energy storage that will be needed in the future due to the intermittent nature of renewable energy sources. In this way an attempt was made to link hydrogen to the development of renewable energy sources whose share in the overall electricity production the EC sought to increase over the next decades. Of course, public research institutes and smaller companies were involved in these expert authorities, too, but they had less influence upon the development of expertise than the policy entrepreneurs. Above all the representatives of the large private enterprises succeeded in establishing themselves as the key experts on H & FC and in asserting their views on these technologies. In so doing, they were supported by the senior officials of the EC who, based on their understanding of innovation, wanted large private enterprises to drive the development of H & FC, as such enterprises would possess the financial resources required to lead H & FC towards commercialization.

The expertise produced was transferred into the policy discourse by the policy entrepreneurs who used it to justify the continuation of a modified Fuel Cell and Hydrogen Joint Undertaking in FP 8 in an Impact Assessment and in the wider policy discourse. While the critics argued that H & FC have been promoted for many years and still have not been commercialized and that the battery technology is much more efficient than H & FC, the supporters of H & FC replied that some niche applications such as forklifts in fact have been commercialized and that the commercialization of H & FC vehicles will take off in the following years. Furthermore, specific expertise was used to outline the advantages of H & FC over the battery technology in order to assert the view that both technologies will be needed to achieve an emission-free transport sector as they serve different segments of the car market. Above all the high-ranking officials at the Director and Director-General level of DG R&I, DG ENER, and DG MOVE of the EC advocated the continuation of the Fuel Cell and Hydrogen Joint Undertaking in Horizon 2020 to their colleagues on the same hierarchical level in the EC and to the Commissioners for Research, Energy, and Transport. In addition, also the representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities had good access to the decision-makers in the EC and promoted the continuation of the Fuel Cell and Hydrogen Joint Undertaking. As a result, the EC proposed to continue a modified Fuel Cell and Hydrogen Joint Undertaking in Horizon 2020 and the Council of the EU adopted this proposal in May 2014.

*Conclusions drawn on the co-production of EU H & FC policy and expertise*

In sum, the preceding paragraphs have illustrated the main empirical findings of this thesis. In so doing, the two main factors that have shaped the co-production of EU H & FC policy and expertise in the years of 2000-2014 according to the empirical findings of this thesis have been outlined: 1) The stage of the policy process, and 2) The role of policy entrepreneurs equipped with specific resources such as financial means and access to decision-makers. However, in order to provide answers to the central research question of this thesis of “How are European hydrogen and fuel cell policy and expertise co-produced?” the empirical findings outlined above have to be raised to a higher level of abstraction. For this purpose, it is helpful to recall the definition of the notion of co-production applied in this thesis which has been outlined in subchapter 3.1. This thesis followed the approach of Sheila Jasanoff (2004) and conceived of co-production as an idiom in order to explore how expertise-making is incorporated into practices of policy-making and, in reverse, how practices of policy-making influence the making of expertise.

The paragraphs above have clearly shown that the practices of policy-making have trumped the making of expertise in the co-production of EU H & FC policy and expertise in the years of 2000-2014. Expertise has been produced according to the dominant policy issues in the four different periods in time. Due to the EC being a public administration, one could also say that the bureaucratic logic of European policy-making has trumped the scientific logic of expertise-making in the co-production of EU H & FC policy and expertise in the years of 2000-2014.

Of course, making this conclusion one has to bear in mind that the chapters outlining the empirical findings of this thesis have been structured by the policy cycle model. However, this does not undermine the validity of this conclusion as it has been demonstrated throughout the chapters 6-9 that the interpretations put forward in this thesis are supported by the empirical data collected. Thus the co-production of EU H & FC policy and expertise in the years of 2000-2014 could also have been categorized in other ways but this would still have resulted in the same main conclusion due to the robust empirical data collected for this thesis: The bureaucratic logic of the policy-making process has trumped the scientific logic of the making of expertise in the co-production of EU H & FC policy and expertise in the years of 2000-2014.

In addition to this bureaucratic logic that has defined the role of expertise in the different stages of the policy process, the specific understanding of innovation of many officials of the EC has also resulted in something which could be termed the commercialization of the making of expertise and of the scientific process in general. To clarify this point further, it is helpful to consider the scholarly literature on policy innovations. This diverse strand of research has been reviewed by Jordan and Huitema (2014) who distinguish between three main perspectives on innovation: 1) invention, 2) diffusion, and 3) effects or impact (Jordan and Huitema 2014, 720). The invention perspective refers to the development of something completely new, that is to say something that has not been used anywhere else before. Diffusion, in contrast, denotes “the process through which these inventions circulate and possibly enter into common use, via processes of learning, transfer, and adoption” (Jordan and Huitema 2014, 720). Hence one of the main differences between invention and diffusion is that an invention is something completely new to the entire world, while diffusion only constitutes something new to the actors that adopt it. Finally, the perspective highlighting the effects or the impact of innovations can be distinguished from inventions and diffusions. As one might expect, this last perspective deals with the effects or the impact that innovations have on the real world. Of course, this impact can range from minor changes affecting only a specific part of a society to substantial transformations of the world (Jordan and Huitema 2014, 720).

Thus the evaluation perspective as described by Jordan and Huitema (2014) is most useful to assess the impact of the new EU R&I policy in the case of H & FC. In so doing, one has to consider three different types of potential impacts: 1) policy outputs, 2) policy outcomes, and 3) policy impacts. While policy outputs refer to changes in the existing policy mix, policy outcomes denote effects on direct target groups and patterns of winners and losers. Finally, policy impacts relate to effects on the wider society, the economy, or the environment (Jordan and Huitema 2014, 722). Indeed, the specific understanding of innovation of many officials of the EC has brought about all three different types of impacts.

First, the way in which innovation was conceived of in the policy discourse has not only impacted the production of expertise on H & FC but also the actual conduct of research on these technologies. The development of H & FC has been guided by the overall objective of leading these technologies towards commercialization. Therefore, the bulk of the funding available in the Fuel Cell and Hydrogen Joint Undertaking has been dedicated to demonstration projects that aimed at the further improvement and validation of already existing technologies in order to move these closer to commercial products that can be sold on the market. This commercialization of the scientific process has gone at the expense of research aiming at reaching a fundamental understanding of new, less-known technologies in the area of H & FC. Hence the new understanding of innovation of many officials of the EC has brought about changes in the actual conduct of research which can be considered as policy impacts on a specific part of the society.

In addition, the new understanding of innovation of many officials of the EC has also brought about policy outcomes as it has affected the target groups of EU R&I policy in the field of H & FC in different ways. In a nutshell, the commercialization of the scientific process has enabled large private enterprises to play the key role in the conduct of research and technology development in the area of H & FC at the expense of public research institutes and universities. Above all, large private enterprises possess the necessary financial means to make the huge investments which are required to lead many H & FC applications to commercialization. In contrast, public research institutes and universities do not possess the necessary financial resources to carry out large demonstration projects with fuel cell vehicles and hydrogen refuelling stations in order to further improve the performance of these technologies. Hence the commercialization of the scientific process has brought about a shift in the scientific authority to define the research and innovation agenda for the development of H & FC from public research institutes and universities towards large private enterprises.

According to the evaluation perspective of Jordan and Huitema (2014), the new understanding of innovation of many officials of the EC has thus had an effect with regard to both policy outcomes and impacts. As a policy outcome, the specific understanding of innovation has brought about a clear pattern of winners (large private enterprises) and losers (public research institutes and universities). As a policy impact, it has affected the governance structure of EU R&I policy and led to changes in the actual conduct of research (Jordan and Huitema 2014, 722). Finally, the new understanding of innovation of many officials of the EC has also brought about impacts in the sense of policy outputs. Indeed, the commercialization of the scientific process in the promotion of H & FC by the EC has resulted in considerable changes in comparison to the Framework Programmes of the 1980s and 1990s, as will be elaborated in more detail in subchapter 10.3 which situates the findings of this thesis in the scholarly literature on EU R&I policy. In sum, it can be concluded that the new understanding of innovation of many officials of the EC has brought about considerable changes in EU R&I policy in the field of H & FC which can be as a commercialization of the scientific process.

In addition to the dominance of the bureaucratic logic and the commercialization of the scientific process, this thesis has also clarified what specific actors have been most influential in the co-production of EU H & FC policy and expertise in the years of 2000-2014. These actors were the high-ranking officials of the EC at the Director and the Director-General level and the representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities who both benefitted from their good access to the decision-makers in the EC. Indeed, the high-ranking officials of the EC at the Director and the Director-General level not only occupy influential positions in the decision-making procedure of the EC but also have close contact to their colleagues on the same hierarchical level and to the Commissioners relevant for their area of interest due to their own positions. Also the representatives of large private companies have good access to the decision-makers in the EC due to the economic importance of their enterprises for the European economy and due to the EC's understanding of innovation. Thus it was the combination of different factors such as a good access to the decision-makers in the EC, financial resources, and the EC's understanding of innovation that enabled the high-ranking officials of the EC and the representatives of large private companies to play the key roles in the two discourses on policy and expertise and to influence the co-production of EU H & FC policy and expertise in the years of 2000-2014 more than other actors such as public research institutes or SMEs.

The following subchapter elaborates in how far these main findings of the dominance of the bureaucratic logic, the commercialization of the scientific process, and the key roles of high-ranking officials of the EC and the representatives of large private enterprises can be generalized beyond this case study of the co-production of EU H & FC policy and expertise in the years of 2000-2014 into wider conclusions on the governance of EU R&I policy.

## 10.2 Insights on the governance of EU research and innovation policy

While EU H & FC policy formed part of the general EU R&I policy throughout the years of 2000-2014, the wider conclusions that can be drawn from this case study are still limited to a specific part of EU R&I policy. The figure beneath situates the funding of H & FC projects in the seventh Framework Programme of the EC indicating why it is difficult to compare the governance of EU H & FC policy with the promotion of other alternative energy technologies in the EU.

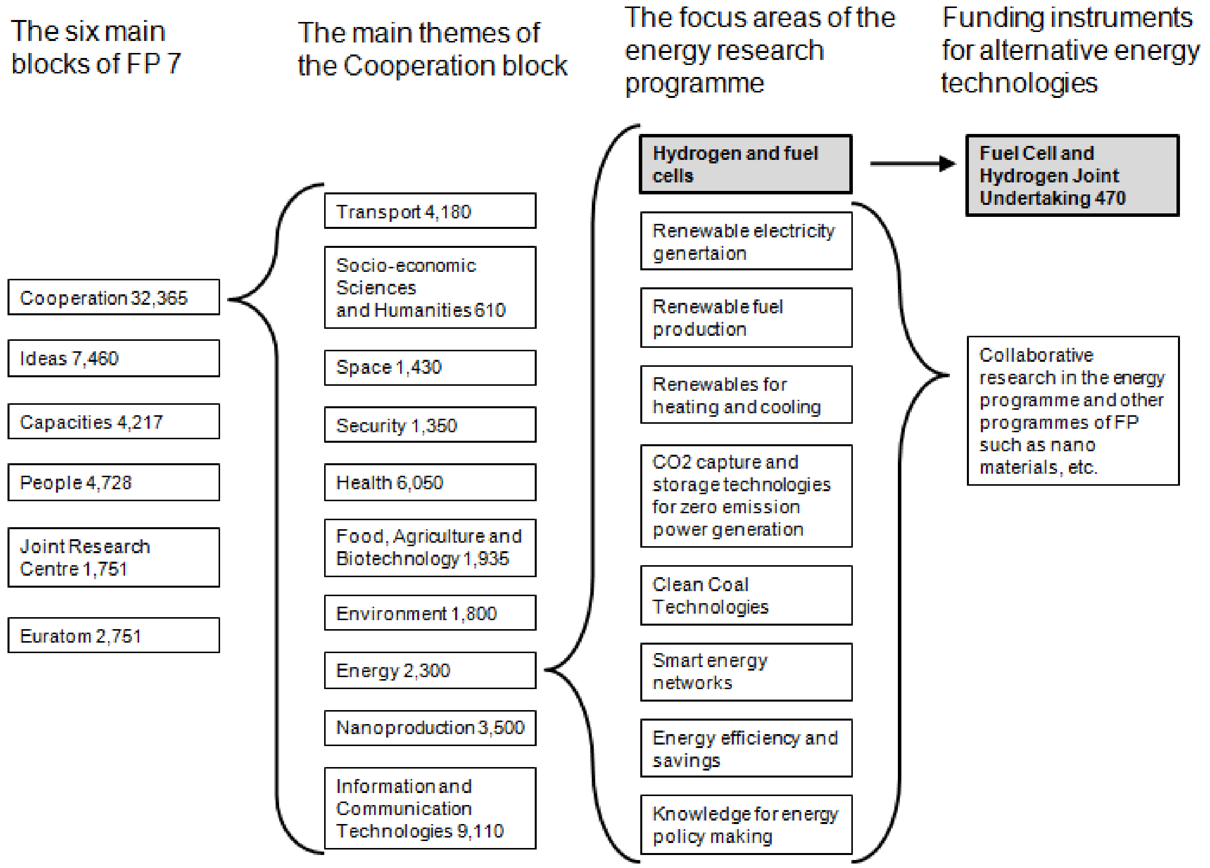



**Figure 17, The funding of H & FC projects in Framework Programme 7**

(the budget of each programme theme is displayed in € million)

Source: (European Commission 2006f, 3, 4)

As can be seen in Figure 17, H & FC have constituted one of the focus areas of the energy research programme that itself was part of the Cooperation block of FP 7. This energy research programme received € 2.3 billion out of the € 53.2 billion of the overall budget of FP 7 (European Commission 2006f, 3, 4). However, in contrast to the other focus areas promoted in the energy research programme such as renewable electricity generation, renewable fuel production, renewable energies for heating and cooling, $CO_2$ capture and storage technologies for zero emission power generation, clean coal technologies, smart energy networks, energy efficiency and savings, and knowledge for energy policy making, in which research projects were funded through collaborative research, funding for H & FC projects was distributed through the Fuel Cell and Hydrogen Joint Undertaking. Thus there was a fixed budget available for projects in the field of H & FC through the launch of the FCH JU, while research projects aiming at the development of other alternative energy technologies had to compete with each other in the calls for proposals of the energy research programme and other programmes in FP 7. Indeed, this centralization of the funding available for certain research and technological areas into specific policy instruments was one of the main purposes of the introduction of Technology Platforms and Joint Technology Initiatives as has been explained in more detail in subchapter 4.3.

These illustrations should clarify the generalizability of the findings of this thesis which can be summed up in three main points. First, the results of this case study of the co-production of EU H & FC policy and expertise can best be compared to the governance of other Technology Platforms and Joint Technology Initiatives of the European Commission. Therefore, it will be elaborated what concrete findings of this thesis can be generalized into wider conclusions on Technology Platforms and Joint Technology Initiatives in a separate subheading below on the basis of the general features of these policy instruments. Above all, it will be pointed out how the results of this thesis shed light on the general governance of these policy instruments and on how specific key actors attempt to influence it.

Second, the illustrations above have also clarified that Technology Platforms and Joint Technology Platforms only account for a comparatively marginal area of the wider EU R&I policy. In fact, the EC only dedicated € 3.12 billion out of the overall budget of € 53.2 billion to the five JTIs of FP 7. Furthermore, a study of the co-production of EU H & FC policy and expertise cannot provide for broader conclusions on the launch of new European research organizations such as the European Research Council or the European Institute of Innovation and Technology. Consequently, this case study of the co-production of EU H & FC policy and expertise does not allow for broader generalizations on the governance of the wider EU R&I policy.

Still, and this is the third point, it is possible to relate selected aspects of the results of this thesis back to the previous findings of the scholarly literature on EU R&I policy. Thus the empirical results of this thesis also allow for instance elaborating in how far the governance of new policy instruments such as Technology Platforms and Joint Technology Initiatives differs from the usual approach of collaborative research in EU R&I policy. This comparison will be made in subchapter 10.3 in which the results of this thesis are situated in the scholarly literature on EU R&I policy in general. First, however, the following paragraphs are to elaborate in how far the empirical results on the governance of the Hydrogen and Fuel Cell Technology Platform and the Fuel Cell and Hydrogen Joint Undertaking allow for wider conclusions on the governance of other Technology Platforms and Joint Technology Initiatives of the EC.

*Insights on Technology Platforms and Joint Technology Initiatives*

In the following paragraphs it will be elaborated in how far the specific findings of this thesis can be generalized into broader conclusions on the EC's new policy instruments of Technology Platforms and Joint Technology Initiatives. As illustrated in the chapters 6-9, the promotion of H & FC by the Technology Platform and the Joint Technology Initiative has been well embedded in the general application of these new R&I policy instruments by the EC. The Hydrogen and Fuel Cell Technology Platform constituted one of the first twenty Technology Platforms launched by the EC in 2004 and the Fuel Cell and Hydrogen Joint Undertaking was one of the first five Joint Technology Initiatives launched in 2008. The application of both policy instruments for the promotion of H & FC was partly shaped by the general guidelines of the EC for these policy instruments. All Technology Platforms were for instance to develop Strategic Research Agendas and all Joint Technology Initiatives underwent interim evaluations in 2010 and 2011.

Hence this case study of EU H & FC policy and expertise allows elaborating in how far general conclusions can be drawn from the main findings of this thesis on the EC's new policy instruments of Technology Platforms and Joint Technology Initiatives. The first of these main findings is that the bureaucratic logic of the policy process has trumped the scientific logic of the production of expertise. More specifically, the dynamics of the four different policy stages identified in the empirical data have defined the dominant policy issues at different points in time which dominated the production of expertise. The second major finding of this thesis on the co-production of EU H & FC policy and expertise was the commercialization of the scientific process through the specific understanding of innovation of the EC. The EC's focus on the commercialization of H & FC enabled large private enterprises to assume leading positions in the development of these technologies due to their financial resources. Third, it has been pointed out that the co-production of EU H & FC policy and expertise has been most influenced by specific policy entrepreneurs such as high-ranking officials of the EC and the representatives of large private enterprises due to a combination of different factors such as financial resources, access to decision-makers, and the EC's understanding of innovation. In addition to these main findings, it will be elaborated at the end of this subchapter in how far the problems encountered in the implementation of the Fuel Cell and Hydrogen Joint Undertaking might have appeared in the implementation of other Joint Technology Initiatives, too.

Indeed, there are some issues that indicate that the other technological areas that have been promoted through Technology Platforms and Joint Technology Initiatives have been influenced by the general dynamics of the different stages in the new EU R&I policy, too. All Joint Technology Initiatives launched in FP 7 have been evaluated in parallel and have been preceded by Technology Platforms and High Level Groups. Thus the process from setting a research and technological area on the European innovation agenda in the first years of the new millennium to the evaluation of the Joint Technology Initiatives at the beginning of the second decade has, at least formally, been a similar one in the case of the five Joint Technology Initiatives launched in 2008. In all five cases a vision document has been produced by a High Level Group in the first years of the new millennium (European Federation of Pharmaceutical Industry and Associations 2004; Group of Personalities 2001; High Level Group 2003; High Level Group Embedded Systems 2004; High Level Group for Nanoelectronics 2004). Thereafter, Strategic Research Agendas have been developed in the Technology Platforms launched for the respective research and technological area (Advisory Council for Aeronautics Research in Europe 2004; Artemis 2005; European Hydrogen & Fuel Cell Technology Platform 2005b; European Nanoelectronics Initiative Advisory Council 2005; The Innovative Medicines Initiative 2005). Finally, the resources allocated in all five research and technological areas had to be distributed during the implementation of the Joint Technology Initiatives (European Commission 2007c, 12; JTI Sherpas' Group 2010, 27–31).

Thus it could be assumed that the co-production of policy and expertise that resulted in the launch of the other four Joint Technology Initiatives has also been dominated by the bureaucratic logic of the policy process and could be categorized into similar stages as the co-production of EU H & FC policy and expertise. This would for instance mean that the development of the vision reports “European Aeronautics: A vision for 2020” (Group of Personalities 2001) and “Creating biomedical R&D leadership for Europe to benefit patients and society” (European Federation of Pharmaceutical Industry and Associations 2004) in the areas of aeronautics and pharmaceutics was shaped by the political objective to raise awareness for these technological areas in the same way as the development of the vision of the hydrogen economy. Provided that this is true, these vision documents would also highlight the future potential of the areas of aeronautics and pharmaceutics for the achievement of EU policy objectives in a rather general manner.

In fact, there are indications that speak for similar stages in the co-production of policy and expertise in the different research and technological areas promoted through Joint Technology Initiatives. The interim evaluations of the different Joint Technology Initiatives for instance have not only been carried out in parallel but also in relation to each other. These were evaluated by the same criteria so that the results allowed a comparison of the performance of the different Joint Technology Initiatives. Thus it appears that the evaluations were mainly conducted for the internal, bureaucratic purposes of the EC as a public administration. For example, in all five evaluations the question of whether the respective public-private partnership should be continued in the future has been an important issue as indicated by the EC's responses to the evaluations (European Commission 2011e).

Hence there are issues that indicate that the bureaucratic logic of the policy process has trumped the scientific logic of the making of expertise in the case of all five research and technological areas for which Joint Technology Initiatives have been launched in 2008. As a consequence, this would mean that the nature of the new EU R&I policy instruments defines the specific role of expertise at different points in time in the policy process. The launch of a Technology Platform for a specific technological area for instance requires expertise to raise the political attention for this area which can be achieved through highlighting the future potential of the technological areas in question for achieving political objectives such as fighting climate change, creating economic growth and jobs, etc. In contrast, the legitimization of the launch of a Joint Technology Initiative would require the definition of more concrete technical objectives to be achieved and the comparison of the technology in question with related technological areas in order to illustrate the specific role and relevance of the technology in question.

In addition to the dominance of the bureaucratic logic over the scientific logic, the second major finding on the co-production of EU H & FC policy and expertise was that the specific understanding of innovation of the EC resulted in a commercialization of the scientific process. This commercialization enabled large private enterprises to play the key role in the development of H & FC due to their financial resources and their good access to the decision-makers in the EC. In so doing, they were supported by the officials of the EC involved in the area of H & FC who primarily conceived of innovation as the development of new commercial products. As a result, the representatives of large private enterprises such as car manufacturers, oil companies, and energy utilities had more influence on the development of H & FC than other actors such as scientists of public research institutes or representatives of smaller companies. In fact, there are several issues that indicate that the EC's specific understanding of innovation has also led to a commercialization of the scientific process in EU R&I policy in general so that there are good reasons to assume that large private enterprises have also dominated the developments in other technological areas as will be outlined in more detail in the following paragraphs.

First, however, it has to be pointed out that it is conceivable that the Joint Technology Initiatives launched in other technological areas brought about different actor constellations than the Fuel Cell and Hydrogen Joint Undertaking. The Innovative Medicines Initiatives aims for instance at accelerating "the development of better and safer medicines for patients" (The Innovative Medicines Initiative 2014). Hence one might wonder whether the development of new medicines attracted the attention of consumer groups or consumer protection associations as many consumers might be able to relate more directly to new medicines that might be prescribed to them in the future than to H & FC vehicles. In a similar vein one might ask whether SMEs played a bigger role in the Artemis Embedded Computing Systems Initiative as the barriers to entry, that is to say the costs to participate in the development of embedded computing systems, might be much lower than the investments required to participate in the development of H & FC vehicles. These reflections should illustrate that it is conceivable that the Joint Technology Initiatives launched in other technological areas brought about other actor constellations than the Fuel Cell and Hydrogen Joint Undertaking so that large private enterprises played a less dominant role.

However, there are also several issues which speak against a bigger role for actors other than large private enterprises in the other Joint Technology Initiatives. These issues are the good access of large private enterprises to the decision-makers in the EC, the EC's general understanding of innovation, and the specific regulations for Joint Technology Initiatives resulting from this understanding of innovation. It seems for instance plausible that the selection of technological areas which are to be promoted through Technology Platforms and Joint Technology Initiatives is most influenced by actors who not only have good access to the decision-makers in the EC but who also possess the financial recourses required for the implementation of large-scale public-private partnerships. One of the key principles of Joint Technology Initiatives is that the financial contribution of the industrial companies involved should at least match the one of the EC. Hence high financial contributions by the EC require the same or even higher financial contributions of the other participants which makes it easier for actors who possess sufficient financial means such as large private companies to play a leading role in Joint Technology Initiatives.

Hence the EC's general understanding of innovation and the specific regulations for Joint Technology Initiatives resulting therefrom support large private enterprises in assuming leading positions in these new policy instruments. Many officials of the EC understand innovation mainly as the development of new commercial products. Consequently, Joint Technology Initiatives are either to contribute to the renewal of existing industrial sectors or to the development of new industrial sectors. This benefits large private enterprises as mainly these possess the financial resources to make the huge investments which are often required for the renewal of existing industrial sectors or the development of new industrial sectors. Therefore, it seems plausible that the commercialization of the scientific process and the key role of large private enterprises resulting from that were not exclusive to the area of H & FC but have also characterized the developments in other technological areas of the new EU R&I policy after the Lisbon Council in March 2000.

Hence this case study of the co-production EU H & FC policy and expertise also underlines how the selection of specific policy instruments such as Joint Technology

Initiatives for certain policy areas affects the actor constellation and the decision-making process in these areas. The launch of the Fuel Cell and Hydrogen Joint Undertaking for instance benefited above all large private enterprises who were enabled to influence the framing of the future prospects of H & FC as well as the allocation of attention and resources to specific technologies in the wider area of H & FC more than any other actors. Thus the findings of this case study emphasize the importance of the decision on what policy instruments are to be applied in what policy fields as the launch of the Fuel Cell and Hydrogen Joint Undertaking had a strong impact on the actor constellation in the field of H & FC in favour of large private enterprises.

These illustrations indicated that it seems plausible that the representatives of large private enterprises have also played a key role in the development of the other Technology Platforms and Joint Technology Initiatives due to a combination of different factors such as a good access to the decision-makers in the EC, financial resources, and the EC's general understanding of innovation. Large enterprises not only possess the resources to employ several persons whose main task is to promote specific issues to the officials of the EC but they also are of a high importance for the European economy due to their high number of employees, their high amount of taxes paid, etc. In addition, many officials of the EC appear to understand innovation mainly as the development of new commercial products which enables large private enterprises to play a leading role in this process as they possess the financial resources required to make the investments for the development of novel technologies. All of these issues grant the representatives of large private enterprises a privileged access to the decision-makers of the EC compared to the scientists of public research institutes or the representatives of smaller companies.

In addition, it also seems plausible that high-ranking officials of the EC at the Director and Director-General level have played key roles in the development of the other Technology Platforms and Joint Technology Initiatives. Senior officials of the EC are almost by definition in close contact with their colleagues at the same hierarchical level and with the Commissioners of the EC who eventually make the formal decisions on what policy instruments are to be applied for the promotion of what technological areas. Hence, due to the hierarchical nature of a public administration, the senior officials of the EC are in close contact to the Commissioners who are in charge of the policy fields in question and can advocate their preferred policy options to these Commissioners. In the case of EU H & FC policy and expertise for instance the most important Commissioners were the Commissioner for Research, the Commissioner for Energy, and the Commissioner for Transport. The high-ranking officials at the Director and Director-General level in DG R&I, DG MOVE, and DG ENER who are supportive of H & FC were in close contact to these Commissioners and could advocate the future potential of H & FC to them.

Thus there are good reasons to assume that the main findings of this single case study can be generalized to other technological areas which have been promoted through Technology Platforms and Joint Technology Initiatives, too. As illustrated above, it seems plausible that the dominance of the bureaucratic logic over the scientific logic, the commercialization of the scientific process, and the strong impact of high-ranking officials of the EC and the representatives of large private enterprises have shaped the launch and the implementation of the Technology Platforms and the Joint Technology Initiatives in technological areas other than H & FC, too. However, in how far these generalized claims can be supported by empirical data can only be proven by a multiple case study of the co-production of policy and expertise in the different technological areas in which Technology Platforms and Joint Technology Initiatives have been launched. This option will be further discussed in subchapter 10.4 in which the opportunities for further research based on the findings of this thesis will be discussed.

Finally, the last paragraphs of this subchapter are dedicated to the elaboration of whether the problems encountered in the implementation of the Fuel Cell and Hydrogen Joint Undertaking are likely to appear in other technological areas as well. The main problems that occurred during the implementation of the Fuel Cell and Hydrogen Joint Undertaking were the different views of the officials of the EC and the industrial companies on the procedure of the assessment of project proposals for funding and on the selection of the staff of the Fuel

Cell and Hydrogen Joint Undertaking. These problems seem to result from a fundamental contradiction in the general regulations on the governance structure of Joint Technology Initiatives. According to these regulations Joint Technology Initiatives are to be led by the industry. Simultaneously, however, the general regulations on the governance structure of Joint Technology Initiatives also reserve a veto right for the EC on all decisions concerning the distribution of the budget.

These two general regulations lead to a fundamental contradiction as most of the important decisions that have to be taken in the implementation of Joint Technology Initiatives concern the distribution of the budget. Not only the procedure of the assessment of project proposals for funding concerns the distribution of the budget but also the selection of the staff as Joint Technology Initiatives are to be fully autonomous organizations which decide on their own how to distribute the budget available. However, Joint Technology Initiatives cannot be fully autonomous organizations if the EC reserves a veto right on all decisions concerning the distribution of the budget because it wants to keep control over the spending of public money and to prevent fraud.

Furthermore, this veto right prevents the industrial companies from leading the development of Joint Technology Initiatives as most decisions upon the distribution of the budget imply decisions on technology development, too. Not only the decisions on what share of the budget is to be dedicated to different technological areas such as hydrogen production or stationary fuel cells concern technology development but also the decisions inside of each technological area on what projects are to be funded and what are not. Different projects in the area of hydrogen production for instance aim at developing different technologies so that decisions about what projects are to be funded also are decisions about what technologies are to be developed in the scope of the Joint Technology Initiative. Hence industrial companies cannot lead the development of novel technologies in Joint Technology Initiatives if the EC keeps the final control over all decisions concerning the distribution of the budget.

Taken to another level of abstraction, these illustrations clarify that the EC pursues a commercialization of the scientific process in its new R&I policy while it simultaneously prevents that this commercialization gains ground in the policy process, too. Indeed, the issue of fraud in the spending of public money and also the spending of public money in general are undoubtedly sensitive political questions. Likewise, however, leading the technological development in a Joint Technology Initiative is inevitably linked to the decisions over its budget. Therefore, it seems plausible and likely that this fundamental contradiction has caused problems in the implementation of other Joint Technology Initiatives, too, because it stems from the general regulations on the governance structure of Joint Technology Initiatives which had to be applied in the implementation of each individual Joint Technology Initiative. Thus different views of the EC and the industrial companies involved over the distribution of the funding and all the related issues such as the procedure of the assessment of project proposals for funding or the selection of the staff seem likely to have arisen in Joint Technology Initiatives other than the Fuel Cell and Hydrogen Joint Undertaking, too.

## 10.3 Contribution to the scholarly literature on the governance of EU R&I policy

The following paragraphs are to situate the main findings of this thesis in the scholarly literature on the governance of EU R&I policy that was outlined in detail in subchapter 2.2. As already emphasized in the preceding subchapter, the findings of this case study primarily allow for drawing wider conclusions on other Technology Platforms and Joint Technology Initiatives of the EC. Consequently, the specific results of this thesis can only be related in selected aspects to the previous findings of the wider scholarly literature on EU R&I policy. Therefore, the following paragraphs will focus on outlining how the concrete empirical findings of this thesis and the theoretical framework developed confirm or supplement the results of previous studies in the area of EU R&I policy.

In so doing, it will also be illustrated how this thesis contributes to filling two gaps in the research on the governance of EU R&I policy. First, this thesis constitutes one of the few empirical studies of the new EU R&I policy that was initiated by the Lisbon Council in March 2000. Second, this thesis sheds light on the role of expertise in the governance of EU R&I policy which so far has been largely neglected by the scholarly literature on this policy field. For this purpose, expertise was not treated as an external variable independent of the policy discourse and the policy subsystem in this thesis but rather as an internal part of the policy subsystem that is produced in parallel and in relation to the policy discourse. Consequently, the following paragraphs underline how the innovative approach of this thesis enriches the scholarly literature on the governance of EU R&I policy by supplementing and confirming previous findings and by providing new insights on this policy field. First, it will be outlined whether and in how far the empirical findings of this thesis confirm or disprove the theoretical assumptions made by different scholars on the governance of EU R&I policy. Thereafter, the additional value that a study of the co-production of policy and expertise contributes to the scholarly literature on EU R&I policy will be illustrated.

Sanz-Menendez and Borrás (2000) have stated that the main objective of the new EU R&I policy after the innovation turn was to move from just catering to the needs of the science and technology community to guiding the development of new technological areas towards technology diffusion and innovation. In fact, the previous European Framework Programmes in the 1980s and 1990s have often been criticized from different actors for only satisfying the demands of the science and technology community instead of setting clear priorities for research and technology development. Thus the new EU R&I policy was to pursue a more strategic approach for the development of new technologies by closer linkages to other EU policies and by becoming more innovation-oriented (Sanz-Menendez and Borrás 2000, 12, 13).

In fact, the empirical results of this thesis suggest that two different aspects should be distinguished in comparing the new EU R&I policy after the Lisbon Council in March 2000 with the Framework Programmes of the 1980s and 1990s. First, one might ask whether new policy instruments such as Technology Platforms and Joint Technology Initiatives have brought about something which might be termed the desired coherence of the approach. That is to say, did these new policy instruments bring about a shift away from just catering to the needs of the science and technology community towards a more strategic, coherent approach in the development of new technologies? In contrast, the second aspect would look at whether the new EU R&I policy has become more innovation-oriented. Of course, “becoming more innovation-oriented” could mean many different things, depending on how innovation is defined and understood. In subchapter 2.1 it has been illustrated that the scholarly literature provides many different conceptions of the process of innovation such as the Triple Helix Model, the systems of innovation approach, etc. Hence comparing the new EU R&I policy with the Framework Programmes of the 1980s and 1990s requires both analysing whether Technology Platforms and Joint Technology Initiatives have brought about a more coherent approach for technology development and highlighting how innovation was conceived of and pursued in practice. The thesis at hand has done both as will be illustrated in the following paragraphs that will clarify in how far a more coherent approach and a stronger focus on innovation was achieved in the promotion of H & FC.

In fact, the empirical findings of this thesis on the case of EU H & FC policy and expertise do not suggest that there have been any substantial changes with regard to achieving a more coherent approach in the development of new technologies in the new EU R&I policy after the Lisbon Council in March 2000. Of course, the launch of new policy instruments such as the Hydrogen and Fuel Cell Technology Platform and the Fuel Cell and Hydrogen Joint Undertaking have brought about a lot of formal changes compared to the usual approach of collaborative research in the Framework Programmes. However, the launch of these policy instruments has not brought about any major changes in the actual setting of the priorities for research and technology development according to the critique of many actors involved in the Hydrogen and Fuel Cell Technology Platform and the Fuel Cell and Hydrogen Joint Undertaking.

Indeed, both the interviews conducted for this thesis as well as the interim evaluation of the Fuel Cell and Hydrogen Joint Undertaking show that many actors criticize the Fuel Cell and Hydrogen Joint Undertaking for focusing too much on satisfying the demands of individual actors and for focusing too little on setting overall priorities for the development of H & FC. Instead, as many actors argue, the Fuel Cell and Hydrogen Joint Undertaking should more actively guide the development of H & FC by defining the overall priorities and pursuing these. Thus the empirical findings of this case study of the co-production of EU H & FC policy and expertise suggest that the formal and organizational changes through the launch of new policy instruments such as Technology Platforms and Joint Technology Initiatives have not brought about the desired coherence of a more guided approach for technology development, at least not as yet.

However, what could be observed in the promotion of H & FC through new policy instruments such as Technology Platforms and Joint Technology Initiatives is an increased focus on leading H & FC towards commercialization. The empirical findings of this thesis have illustrated that the EC's general understanding of innovation as the development of new commercial products has had a strong impact on the co-production of EU H & FC policy and expertise in the years of 2000-2014. It was this understanding of innovation that supported the large private enterprises to assume leading positions in the development of H & FC and to assert a focus on large-scale demonstration projects in the Fuel Cell and Hydrogen Joint Undertaking. In contrast, this specific understanding of innovation of many officials of the EC made it difficult for public research institutes and universities to assert a focus on research aiming at the fundamental understanding of new technologies. Hence many of the projects funded by the Fuel Cell and Hydrogen Joint Undertaking aimed at the improvement and the further validation of existing technologies in order to for instance increase the lifetime of fuel cells or to reduce their costs, while only few projects focused on exploring new, less-known technologies. Thus the empirical findings of this thesis suggest that the new EU R&I policy has indeed become more innovation-oriented according to the specific understanding of innovation of many officials of the EC.

These illustrations clarified how the empirical findings of this thesis relate to the observations of Sanz-Menendez and Borrás (2000) on the innovation turn in EU R&I policy in the late 1990s. For this purpose, it was pointed out that one has to distinguish between two aspects that the innovation turn was to bring about in comparison with the Framework Programmes of the 1980s and 1990s: 1) The EC's desired coherence in technology development, and 2) the increased focus on innovation. With regard to the first aspect of a more coherent approach for technology development, the empirical findings of this thesis suggest that this could not be achieved in the promotion of H & FC, yet. Indeed, many actors criticised the Fuel Cell and Hydrogen Joint Undertaking for the lack of a coherent approach in the development of H & FC and for too much just pursuing the particular interests of individual actors. With regard to the second aspect, however, the empirical findings of this thesis suggest that the new EU R&I policy has indeed become more innovation-oriented according to the specific understanding of innovation of many officials of the EC. The Fuel Cell and Hydrogen Joint Undertaking focuses rather on leading existing, well-known H & FC technologies towards commercialization than on reaching a fundamental understanding of comparably new, less-known technologies in the area of H & FC. Indeed, this focus is fully in line with the EC's understanding of innovation in which innovation is mainly conceived of as the development of new commercial products. Thus, while the Hydrogen and Fuel Cell Technology Platform and the Fuel Cell and Hydrogen Joint Undertaking have not brought about the desired coherence in the development of H & FC, yet, the officials of the EC succeeded in establishing a stronger focus on innovation in these new policy instruments according to the EC's specific understanding of innovation in which innovation is mainly conceived of as the development of new commercial products.

The empirical findings of this thesis also clarify in how far Kuhlmann's (2001) three scenarios for the future development of the new EU R&I policy after the Lisbon Council in March 2000 have materialised in the case of EU H & FC policy and expertise . Kuhlmann has distinguished between a centralized EU R&I policy with the EC as the key actor, a decentralized European R&I arena with open competition between national and regional innovation systems, and a mixture of competition and cooperation between national and regional innovation arenas mediated by European institutions. In Kuhlmann's view the first scenario of a centralized EU R&I policy was deemed to fail because of an overload of policy complexity and the resistance of the Member States and national research institutes. In the second scenario of a decentralized European R&I arena Kuhlmann saw the risk that regions and Member States with lower innovation capabilities could fall further behind (Kuhlmann 2001, 972).

Indeed, the empirical findings of this thesis confirm these risks in the case of EU H & FC policy and expertise. The parallel launch of the Fuel Cell and Hydrogen Joint Undertaking and a national public-private partnership for the promotion of H & FC in Germany has led to an overload of policy complexity and to regions and Member States with few or no research activities in H & FC falling further behind in the development of these technologies. The members of the States Representative's Group of the Fuel Cell and Hydrogen Joint Undertaking lack the resources in the form of time and authority to coordinate national and European H & FC policies with each other. This has the result that a systemic coordination between national and European H & FC policies actually does not take place because many representatives either lack the authority to initiate or to adjust national H & FC activities to the European ones or the time to systematically coordinate large national H & FC programmes with the European public-private partnership.

The distribution of the budget of the Fuel Cell and Hydrogen Joint Undertaking among public and private organizations from different Member States has also shown that the bulk of the funding available goes to countries which already had national H & FC activities before the launch of the European public-private partnership. In contrast, the launch of the Fuel Cell and Hydrogen Joint Undertaking has only marginally triggered H & FC activities in countries which did not invest in these technologies before such as for instance many of the most recent Member States from Eastern Europe. Hence the launch of a European public-private partnership has in fact increased the gap in the development of H & FC between countries which already did invest in these technologies before and those that did not. It appears that the launch of the Fuel Cell and Hydrogen Joint Undertaking has mainly triggered larger investments of public and private organizations which had already invested in the development of H & FC, while it only marginally initiated H & FC activities in the case of organizations that did not deal with these technologies before.

In sum, the empirical findings of this thesis do not ideally fit into any of the three scenarios outlined by Stefan Kuhlmann. Of course, the officials descriptions and objectives of what the launch of the Fuel Cell and Hydrogen Joint Undertaking was to achieve fit best with the third scenario of a mixture of competition and cooperation between national and regional innovation arenas mediated by European institutions. However, this mediation between national and regional innovation systems by the Fuel Cell and Hydrogen Joint Undertaking has not taken place in a systematic way due to a lack of resources in the States Representatives' Group. Rather, what is taking place in the case of the Fuel Cell and Hydrogen Joint Undertaking could be described as the parallel existence of European, national, and regional institutions for the promotion of H & FC without a systematic coordination between them.

In spite of the concentration of EU H & FC projects on a certain group of Member States, the empirical findings of this thesis clearly show that the implementation of the Fuel Cell and Hydrogen Joint Undertaking has increased cross-border cooperation among scientists in the EU. This actual interaction of scientists across borders in EU funded research projects was highlighted by several scholars (e.g. Edler and Kuhlmann 2012; Luukkonen and Nedeva 2010; Nedeva 2013) who theoretically elaborated whether EU R&I policy increases cross-border cooperation among scientists. The build-up of European associations such as the N.ERGHY Research Grouping for public research institutes and universities and the NEW Industry Grouping for private companies speaks for an increased interaction of actors from different Member States with an interest in H & FC, even if the most active member organizations only come from a limited number of countries. Indeed, the bulk of the budget of the Fuel Cell and Hydrogen Joint Undertaking is distributed among organizations based in Germany, the UK, Italy, Denmark, and France. Thus the Fuel Cell and Hydrogen Joint

Undertaking appears to mainly have triggered cross-border cooperation among actors who already performed national H & FC activities before, while it only marginally increased the uptake of new H & FC activities in countries in which there have not been any H & FC activities before.

While the paragraphs above have focused on outlining whether the empirical findings of this thesis confirm or disprove the theoretical assumptions made by different scholars on the governance of EU R&I policy, the following paragraphs will illustrate the additional value that a study of the co-production of policy and expertise contributes to the scholarly literature on EU R&I policy. Studies such as that of John Peterson (1991) for instance have merely focused on the different interests of the EC, the Member States, and the industry in their explanation of the governance of EU R&I policy. In contrast, this thesis has highlighted the different roles that expertise played in the development of EU H & FC policy in the years of 2000-2014.

In the first years of the new millennium the promising vision of a hydrogen economy helped certain actors to set H & FC on the European agenda without any larger opposition. The critique of the hydrogen economy was marginal and only raised by a few actors. While all the different interests of the actors involved in setting H & FC on the European agenda cannot be elaborated in the scope of this thesis, there are good reasons to assume that the promising vision of the hydrogen economy had contributed to keeping the critique at a low level. This was not least the case because there was no counter expertise at that time highlighting other technologies that would be able to contribute to an emission-free transport system in the future. Rather, the battery technology was discarded as a viable option to achieve an emission-free transport system by the officials of the EC at that time. Thus the promising vision of a hydrogen economy and the lack of counter expertise have certainly made it easier to raise attention and to gather political support for setting H & FC on the European agenda.

A few years later in 2007 and 2008 not only had the expertise on H & FC changed, but also views on battery technology, resulting in a significant increase in the level of criticism of

H & FC. Technological progress in the development of the battery technology has led many actors, including many officials of the EC, to alter their views on this technology so that in 2007 and 2008 batteries were perceived by many actors as the most efficient technology to achieve an emission-free transport system in the future. As a result, many supporters of the battery technology criticized H & FC as inefficient. However, the supporters of H & FC developed counter expertise portraying H & FC and batteries in a complementary relationship to each other. H & FC were outlined as one among other new, low carbon energy technologies in order to justify the launch of the Fuel Cell and Hydrogen Joint Undertaking. The expertise outlining the specific role of H & FC in a future emission-free energy and transport system helped the supporters of these technologies to make H & FC one of the new energy technologies which were promoted by the EC in FP 7.

These illustrations clarify the importance of expertise in the governance of EU R&I policy. The way in which certain technologies are perceived and portrayed affects the political support for them as well the political opposition to them. Thus the findings of this thesis suggest that expertise can have an impact on the interests of specific actors. While the vision of the hydrogen economy helped the proponents of H & FC to gather support for setting these technologies on the European agenda in the first years of the new millennium, the development of new expertise on the future potential of the battery technology brought about further critique of H & FC as energy inefficient technologies. Hence expertise affects the view of specific actors on science and technology and plays an important role in the governance of EU R&I policy. Therefore, future studies should not treat expertise as an external variable independent of the policy discourse but rather consider its production as an internal part of the policy subsystem which should be included in any analysis of the governance of EU R&I policy.

The inclusion of expertise into this analysis of the promotion of H & FC by the EU also illustrates the relevance of this thesis with regard to the studies of Hervás Soriano & Mulatero (2011) and Rodriguez et al. (2013). Hervás Soriano & Mulatero (2011) have shed light on the role of the Strategic Energy Technology Plan of the EC for the development of renewable energies. The authors have emphasized that the Strategic Energy Technology Plan and its information system in the form of an open-access platform for the exchange of technical data which is managed by the Joint Research Centre have contributed to increased policy integration and efficient governance. According to the findings of the authors, the Strategic Energy Technology Plan has helped to mobilize and coordinate different actors and to align the development of renewable energy technologies and different policy initiatives to the overall policy objectives of the EC for 2020 and to the long-term objectives for 2050 (Hervás Soriano and Mulatero 2011, 3585-3589).

While the empirical results of this thesis confirm these findings, the theoretical insights gained through the focus on the co-production of policy and expertise supplement the study of Hervás Soriano & Mulatero (2011). As chapter 8 and 9 have illustrated, the Strategic Energy Technology Plan and its information system managed by the Joint Research Centre have played important roles in the negotiations of the launch the Fuel Cell and Hydrogen Joint Undertaking and in the discussions on the continuation of the Fuel Cell and Hydrogen Joint Undertaking. During the development of the Strategic Energy Technology Plan in 2007, the supporters of H & FC had to ensure that H & FC are included in it as one of the new energy technologies that will be needed to achieve the objectives of EU energy policy in the future in order to legitimize the launch the Fuel Cell and Hydrogen Joint Undertaking. At the time of the discussions on the continuation of the Fuel Cell and Hydrogen Joint Undertaking in 2011-2014, the information system of the Strategic Energy Technology Plan was fully in place and the supporters of H & FC in the Join Research Centre contributed to justifying the continuation of the Fuel Cell and Hydrogen Joint Undertaking by providing specific expertise on H & FC.

Hence the findings of this thesis not only confirm the results of the study of Hervás Soriano & Mulatero (2011) but also supplement these as the analysis of the co-production of EU H & FC policy and expertise provides an example of how specific technologies can become part of the Strategic Energy Technology Plan. While Hervás Soriano & Mulatero (2011) have shed light on the impact of policy in the form of the Strategic Energy Technology

Plan on technology development, this thesis has illustrated how the development of specific technologies affects the set-up and the implementation of the Strategic Energy Technology Plan. Above all in chapter 8 it was outlined how the Joint Research Centre produces the expertise for the information system on which the implementation of the Strategic Energy Technology Plan is based. Hence this study of the co-production of EU H & FC policy and expertise has not only highlighted the impact of the Strategic Energy Technology Plan on the promotion of H & FC but also how the promotion of H & FC affects the further development of the Strategic Energy Technology Plan and its information system.

Rodriguez et al. (2013) have found in their empirical investigation of the implementation of EU R&I policy that there is an increasing tendency to frame the research projects funded in the Framework Programmes in socio-economic and industrial terms. The findings of this thesis confirm and supplement these results in several ways. In fact, throughout the years of 2000-2014 H & FC were portrayed as key components of a future emission-free energy and transport system that would strengthen the competitiveness of the European industry and contribute to economic growth and the creation of new jobs. Hence the main objective of EU H & FC policy was to lead these technologies towards commercialization. This focus on the commercialization of H & FC in the promotion of these technologies by the EU confirms the increasing tendency to frame the research projects in socio-economic and industrial terms that was attested by Rodriguez et al. (2013).

In addition, the findings of this thesis show that the focus on the commercialization of H & FC stems from the EC's general understanding of innovation in which innovation is mainly perceived as the development of new commercial products. Consequently, new policy instruments of EU R&I policy such as Technology Platforms and Joint Technology Initiatives aim at developing new industrial sectors in the EU or at renewing existing ones. In the case of the Fuel Cell and Hydrogen Joint Undertaking this understanding of innovation as new commercial products enabled the industrial companies involved to play a leading role in setting the research and development priorities for H & FC. Hence the focus of the projects funded through the Fuel Cell and Hydrogen Joint Undertaking is much more on large-scale demonstration projects than on basic research aiming at the fundamental understanding of new technologies. The objective is rather to validate and improve existing technologies than to explore novel, less-known technologies. Hence, in the case of H & FC, the framing of concrete research projects in socio-economic and industrial terms stems from the overall focus of the new EU R&I policy which mainly perceives innovation as new commercial products.

## 10.4 Opportunities for further research

The findings of this thesis open up various opportunities for further research in the two fields of Public Policy literature and Science and Technology Studies. The following paragraphs will first outline how further studies building on the findings of this thesis could contribute to the wider Public Policy literature before it will be pointed out how new research contributing to the field of Science and Technology Studies could build on the findings of this thesis. In so doing, the structure of this subchapter is built on the insights on the generalizability of the findings of this thesis gained in subchapter 10.2 in which it has been emphasized that the main results of this case study of EU H & FC policy primarily allow for drawing wider conclusions on other Technology Platforms and Joint Technology Initiatives. Consequently, it will first be outlined in the following paragraphs how multiple-case studies of other Technology Platforms and Joint Technology Initiatives could built on the findings of this thesis. Thereafter, it will be illustrated how the concrete empirical findings on the co-production of EU H & FC policy and expertise provide the foundation for further research on the development of these technologies from specific Science and Technology Studies approaches such as innovation systems and multi-level perspectives.

As already indicated in subchapter 10.2, the most obvious way to examine whether the empirical results of this investigation of the Hydrogen and Fuel Cell Technology Platform and the Fuel Cell and Hydrogen Joint Undertaking can be generalized to the wider EU R&I policy would be to conduct a multiple case study of other Technology Platforms and Joint Technology Initiatives of the EC. Such a multiple case study could clarify whether the co-production of policy and expertise in the other Technology Platforms and Joint Technology Initiatives was also shaped by bureaucratic logic of the policy process and whether the development of these policy instruments was also driven by high-ranking officials of the EC and the representatives of large private enterprises. In this way it could be clarified whether other Technology Platforms and Joint Technology Initiatives have been driven by different groups of actors than the Hydrogen and Fuel Cell Technology Platform and the Fuel Cell and Hydrogen Joint Undertaking. Have consumer protection associations or SMEs played a bigger role in the Innovative Medicine Initiative or in the Artemis Embedded Computing Systems Initiative? Hence a multiple case study of other Technology Platforms and Joint Technology Initiatives could highlight whether the EC's understanding of innovation as the development of new commercial products has also resulted in the commercialization of the scientific process in the other technological areas promoted through the new EU R&I policy. Among others, this would illustrate whether the new EU R&I policy and the EC's understanding of innovation benefits large private enterprises in general or whether it in some cases also enables other actors such as SMEs or NGOs to play a more important role in research and technology development.

In addition, such a multiple case study could shed light on the impact of the internal, bureaucratic processes of a public administration such as the European Commission on the assessment and development of Technology Platforms and Joint Technology Initiatives. It could for instance be investigated in how far the development of the different Technology Platforms and the Joint Technology Initiatives is discussed inside of the EC and influences each other. In fact, an in-depth investigation of the internal discussions of the EC could also help to further elucidate the importance of expertise in EU R&I policy. Such an investigation could focus on how the application of policy instruments such as Technology Platforms and Joint Technology Initiatives to specific research and technological areas is discussed inside of the EC. In this way such a study could supplement the findings of this thesis which has highlighted how the launch of the Hydrogen and Fuel Cell Technology Platform and the Fuel Cell and Hydrogen Joint Undertaking was promoted in the EC and defended against critique by the EC officials supportive of H & FC. However, as the focus of this thesis was on explaining the co-production of EU H & FC policy and expertise, it was not directly highlighted what other alternatives might have been discussed in the EC. This issue could be dealt with in more detail by a study that focuses more explicitly on the selection of certain policy instruments for the promotion of specific technological areas and on the internal discussions in the EC.

Hence one might ask how it is decided what technological areas are to be promoted through what policy instruments and what role expertise and the internal dynamics of a public administration play in this process. The findings of this thesis have for instance shown that during the negotiations of launch of the Fuel Cell and Hydrogen Joint Undertaking H & FC were most heavily criticised by the supporters of the battery technology in the EC. In the end, around one year after the launch of the Fuel Cell and Hydrogen Joint Undertaking in 2008, the EC also launched the public-private partnership Green Car Initiative which mainly focused on the promotion of battery electric vehicles. Thus an in-depth investigation of the internal discussions of the EC could supplement the findings of this thesis by further clarifying how related technological areas with overlapping areas of application are discussed internally in the EC and how it is decided what policy instruments are to be applied for the promotion of the different technological areas. Does this decision rely on expertise outlining the specific technological requirements of a certain technological area which can be better met by a specific policy instrument than by other ones or is the decision more influenced by the internal logics of a public administration irrespective of the expertise on the different technological areas? By shedding light on these questions, a multiple case study of the different Technology Platforms and Joint Technology Initiatives could also contribute new insights to the wider literature on public policy instruments and public policy instrumentation (e.g. Lascoumes and Le Gales 2007).

Furthermore, an in-depth investigation of the internal negotiations of the EC on the application of certain policy instruments for specific technological areas could also shed light on how different non-related technological areas are discussed in this process. This could further clarify the role of expertise, of the internal, bureaucratic dynamics of the EC, and of the overall EU policy objectives on the application of certain policy instruments for the promotion of specific technological areas. One might for instance ask why the Hydrogen and Fuel Cell Technology Platform was converted into a Joint Technology Initiative while the Water Supply and Sanitation Technology Platform was not. Did this rely on the expertise produced on both technological areas or did H & FC fit better into the overall EU policy objectives such as strengthening the competitiveness of the European industry and fighting climate change than the technological area covering water supply and sanitation?

These illustrations show how an in-depth study of the internal discussions of the EC on R&I policy could build on the findings of this thesis and contribute further insights to the Public Policy literature on the governance of EU R&I policy. In addition to these opportunities for further research contributing to the Public Policy literature, the concrete empirical findings of this thesis have also laid the foundations for different investigations with approaches from the Science and Technology Studies. While the many different theoretical approaches present in the field of the Science and Technology Studies would allow for a wide variety of different studies to build on the findings of this thesis, the following paragraphs will focus on indicating some opportunities for further research based on the two approaches of innovation systems and multi-level perspectives which have gained increasing popularity in the Science and Technology Studies community over the past decades.

A study from the multi-level perspective that was put forward by Geels (Geels 2002) could produce new insights on the development of H & FC in the EU by building on the results of the thesis at hand. While this thesis has outlined that a systemic coordination between European and national H & FC policies does not take place, yet, an investigation from a multi-level perspective could further clarify how the parallel existence of European and national H & FC policies impacts the actual development of these technologies on the regional and on the local level. Hence a study of the development of H & FC from a multi-level perspective could highlight whether and in how far European and national H & FC policies trigger the development of regional and local networks for the development of H & FC.

Hence the multi-level perspective would allow investigating in how far a technological transition from niches to landscapes and eventually to regimes is actually taking place in the development of H & FC by focusing on the linkages and connections that have been built up between different regional and local networks. As this thesis has outlined that the co-production of EU H & FC policy and expertise is mainly led by high-ranking officials of the EC and large private enterprises one might ask whether and in how far large private enterprises also dominate the actual development of H & FC. Thus a study from a multi-level perspective could clarify in how far local and regional networks for the development of H & FC only cluster around large private enterprises and in how far large private enterprises shape the formation of standards, niches, and markets according to their preferences. In this way new insights could be gained on how the technological transition on the level of niches, landscapes, and regimes takes place in the case of H & FC.

In addition to the multi-level perspective, also a study of the development of H & FC in the EU based on the innovation system approach could be built on the findings of this thesis. While this thesis focused on explaining the co-production of EU H & FC policy and expertise, a study applying the innovation system approach could focus more on the technical and economic development of H & FC. In this way it could be clarified in how far the EC has succeeded in achieving the objectives of its new understanding of innovation as the development of new commercial products. That is to say, it could be clarified in how far the Hydrogen and Fuel Cell Technology Platform and the Fuel Cell and Hydrogen Joint Undertaking actually contributed to market formation, standardization, technical progress etc. in the area of H & FC.

This would illustrate in how far the commercialization of the scientific process in the new EU R&I policy has contributed to the development of new commercial products in practice.

Of course, in part this thesis touched upon these issues as well but they have not been the primary focus of this study. While this thesis outlined that the EC's new understanding of innovation enabled large private enterprises to set the focus of the Fuel Cell and Hydrogen Joint Undertaking on the further improvement and validation of existing, well-known technologies and the funding of large-scale demonstration projects, a study of the development of H & FC from the innovation system perspective could result in new insights on the actual impact of this EU H & FC policy on the development of new commercial products in the area of H & FC. In other words, while this thesis has shown that the EC pursues a commercialization of the scientific process in its new EU R&I policy, a study from the innovation system perspective could show in how far the EC is successful in doing this.

Hence such a study could clarify whether or in how far the European policy instruments for the promotion of H & FC have contributed to the emergence of a European H & FC innovation system. The findings of this thesis show that the Joint Technology Initiative for H & FC has above all triggered cooperation among public and private organizations based in Germany, the UK, Italy, Denmark, and France which in common carry out research projects funded by the Fuel Cell and Hydrogen Joint Undertaking. A study from an innovation system perspective could further clarify whether this cooperation extends beyond the common research projects to the development of formal standards and other aspects of market formation or whether the cooperation is limited to the collection of funding from the Fuel Cell and Hydrogen Joint Undertaking.

This would also allow elaborating whether the development of H & FC in the EU is mostly led by regional, national, or European innovation systems. For this purpose, such a study would have to supplement the findings of this thesis on the interactions of the different public and private actors in the production of expertise through a stronger focus on the interactions of these actors in the actual development of H & FC. In this way it could be clarified in how far cooperation on standardization, the development of value chains, etc. has actually been built up on the European level and in how far this cooperation is rather driven by regional or national innovation systems. Thus a study of the development of H & FC in the EU from an innovation system perspective could help to further highlight in how far the Fuel Cell and Hydrogen Joint Undertaking has contributed to increased cross-border cooperation in the development of these technologies.

Finally, one might ask in how far a study of the development of H & FC from an innovation system perspective would confirm the findings of this thesis on the co-production of EU H & FC policy and expertise. This thesis has illustrated that the bureaucratic logic of the policy process has trumped the scientific logic in the making of expertise in the case of H & FC. The role of expertise in the policy discourse was defined by the different stages of the policy process. Thus one might wonder whether a study of the promotion of H & FC from an innovation system perspective would come to the same conclusion.

Part of the answer is, of course, that a study from an innovation system perspective would look at slightly different issues than this thesis. As illustrated above, the focus of such a study would be less on policy and expertise and more on the general development of the innovation system including issues such as market formation, patents, standardization, technical progress etc. Hence the central research question of this thesis “How are EU hydrogen and fuel cell policy and expertise co-produced?” would only be one of several subquestions in a study of the promotion of H & FC by the EC from an innovation system perspective.

However, one of the key arguments of this thesis was exactly that policy and expertise are two closely interwoven phenomena that can best be understood if analyzed together. The main point of the theoretical framework put forward was to demonstrate that combining the two disciplinary fields of Science and Technology Studies and Public Policy in a profitable manner provides a useful tool for the analysis of the co-production of policy and expertise. While many Public Policy approaches treat the production of expertise as an external, independent factor, this thesis has shown that analyzing policy and expertise together provides an additional value by facilitating a deeper understanding of these two phenomena and their complex relation to each other.

Thus this thesis could also serve as an inspiration for further studies exploring the interface of policy and expertise and the potential combinations of the two disciplinary fields of Science and Technology Studies and Public Policy. In this thesis the Discourse Coalitions approach from the field of Public Policy has been combined with the scholarly literature on the provision of expertise from the Science and Technology Studies. By this means the discourse on expertise was integrated into the policy subsystem which enabled the analysis of the interface of the two discourses on policy and expertise. In a similar manner, future studies could build on the innovation system approach or the multi-level perspective of the Science and Technology Studies and combine these with specific approaches from the Public Policy literature such as the Advocacy Coalition Framework. Shedding light on the co-production of policy and expertise from different theoretical perspectives would provide new insights on the interdependence of these two phenomena.

In this way further research from different theoretical angles could pave the way for a more systematic understanding of the co-production of policy and expertise. This thesis has demonstrated the benefits of an approach that analyzes policy and expertise together. In so doing it has opened the door to a wide variety of potential future studies highlighting the complex relationship between the two phenomena of policy and expertise.

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# Annex

## Abbreviations

| | |
|---|---|
| ACF | Advocacy Coalition Framework |
| CEO | Chief Executive Officer |
| DG | Directorate-General |
| EC | European Commission |
| ENER | Energy |
| EP | European Parliament |
| ERA | European Research Area |
| EU | European Union |
| FCH JU | Fuel Cell & Hydrogen Joint Undertaking |
| FP | Framework Programme |
| GHG | Greenhouse Gas |
| HFP | Hydrogen and Fuel Cell Technology Platform |
| HLG | High Level Group |
| H & FC | Hydrogen and Fuel Cell Technologies |
| IA | Impact Assessment |
| IUS | Innovation Union Scoreboard |
| JTI | Joint Technology Initiative |
| MCFC | Molten Carbonate Fuel Cells |
| MEP | Member of the European Parliament |
| MOVE | Mobility and Transport |
| PAFC | Phosphoric Acid Fuel Cells |
| PEFC | Proton Exchange Membrane Fuel Cells |
| PNF | Policy Narratives Framework |
| R&D | Research and Development |

| | |
|---|---|
| R&I | Research and Innovation |
| SME | Small and Medium-Sized Company |
| SOFC | Solid Oxide Fuel Cells |
| TP | Technology Platform |
| TREN | Transport and Energy |
| USA | United States of America |

List of interviewees

| Interviewee | Date of the interview | Occupation / Positions in EU H & FC institutions |
|---|---|---|
| 1 | 07.11.2011 | Scientist of a public research institute; Involved in the HFP; Member of the Scientific Committee of the FCH JU |
| 2 | 24.01.2012 | Representative of a car manufacturer; Member of the HLG; Involved in the HFP |
| 3 | 07.11.2011 | CEO of a SME; Member of the HLG; Involved in the HFP; Involved in FCHInStruct |
| 4 | 24.11.2011 | Scientific Officer of DG Research & Innovation of the EC; Involved in the HLG, the HFP, and the FCH JU |
| 5 | 22.01.2013 | Representative of private company; Involved in the HFP, and the FCH JU |
| 6 | 25.01.2012 | Member of the European Parliament (The Greens/European Free Alliance) |
| 7 | 20.12.2011 | Official of the national German administration |
| 8 | 23.01.2012 | Scientist of a public research institute; Member of the HLG; Involved in the HFP, and in the FCH JU |
| 9 | 16.04.2013 | Scientist of the Joint Research Centre of the EC |
| 10 | 24.06.2013 | Representative of private company; Involved in the HFP, and the FCH JU |
| 11 | 23.04.2013 | Scientific Officer of DG Research & Innovation of the EC; Involved in the FCH JU |
| 12 | 24.01.2013 | Member of the expert panel that conducted the first interim evaluation of the FCH JU |
| 13 | 18.02.2014 | Scientific Officer of DG MOVE of the EC; Involved in the FCH JU |
| 14 | 22.08.2013 | Scientific Officer of DG Research & Innovation of the EC; Involved in the HLG, the HFP, and the FCH JU |
| 15 | 17.01.2012 | Representative of an private company; Involved in the HFP, and in the FCH JU |
| 16 | 23.06.2013 | Representative of a NGO; Involved in the HFP |
| 17 | 16.06.2013 | Scientist of the Joint Research Centre of the EC |
| 18 | 26.01.2012 | Executive Director of the FCH JU |
| 19 | 26.01.2012 | Commissioner for Research of the EC |
| 20 | 12.01.2012 | Representative of a car manufacturer; Member of the HLG; Involved in the HFP, and in the FCH JU |